DOCTOR OF PHILOSOPHY

The Physics Laboratory in Higher Education in Libya

Ali Hamed, Saffia

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University of Dundee
College of Arts & Social Sciences
School of Education, Social Work & Community Education

The Physics Laboratory in Higher Education in Libya

By

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A Thesis Submitted for the Degree of Doctor of Philosophy (PhD)

College of Arts and Social Sciences

School of Education

University of Dundee

بِسْمِ اللّٰهِ الرَّحْمَٰنِ الرَّحِيمِ

{يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ} (القرآن الكريم، 58:11)

In the name of God, the Most Gracious, the Most Merciful.

"Allah will raise those who have believed among you and those who were given knowledge, by degrees."[Qur'an, 58:11]

Dedicated to ...

my husband Alsaid,

my mother

&

my children, Abdulhaq, Altaher and Jawhara

Abstract

Laboratory work is considered to be a vital part of the entire learning experience in physics and work in the laboratory has the potential to help make physics more real and tangible for the students while they can develop experimental design skills as well as developing observational and problem-solving skills. Sometimes, difficult concepts can be illustrated while laboratory work also offers opportunities for learners to develop skills in thinking, questioning, planning, and interpreting data as well as an opportunity to develop group working skills. Above all, physics, like all other sciences, gains its insights by means of experimentation and learners need experience of this.

In addition, laboratory work has an important role in understanding a subject like physics in that it can make physics more real for the students. More importantly, there is great scope for developing laboratory learning which will enhance understanding as well as give the students an experience of how experimental evidence is used to develop the insights in physics. The question here is: does laboratory courses in higher education actually achieve these goals in a developing country such as Libya where the laboratories are not highly equipped while the staff and the teachers are not trained adequately?

Studies have shown that, in laboratory learning, students follow instruction sheets like recipes with little understanding what they are doing, tending to generate negative attitudes. Some key studies have shown clearly that cognitive overload is the source of the problem: the learner's has to cope with too many ideas at the same time. This study explored this idea and considered how the cognitive load can be reduced, enabling cognitive capacity to be available for greater understanding.The

entire work was carried out on three stages with the students in the Faculty of Science at Sebha University, a typical university in Libya.

The first experimental study (N = 150) aimed to gain an overall picture of the problems in Libya, look at how learners saw their school and their university experiences in laboratory work in physics. Questionnaires were designed to establish a picture of what was going on and where the problems lay. The survey showed the learners' need for the security of instruction sheets but they were following these like recipes and not understanding what they were doing.

In the light of these findings, pre-laboratory exercises were designed and post-laboratory exercises were constructed, for each experiment. The pre-laboratory exercise involved a set of simple tasks for the students to complete allowing them to revise underpinning ideas, grasp the key point of the experiment and how it was to be done. The overall aim was to reduce the pressure on limited working memory capacity as they undertook the experiment. The post-laboratory exercises were also short and were designed to allow the students to apply the ideas they had learned. The post-laboratory exercises were marked and the scores were used as a measure of understanding.

When used with a sample of students (N = 95, fifth semester), the changes brought about by the use of pre-laboratory exercises were explored by considering their performance in the post-laboratory exercises while student perceptions of the experience were considered using a questionnaire. It was found that the pre-laboratory exercises improved understanding quite markedly with the students at Sebha University and their attitudes towards the whole pre-laboratory experience was very positive.

In the third and final stage, pre-laboratory and post-laboratory were also employed with a sample of students (N = 106, fifth semester)but the post-lab exercises were extended considerably. The laboratory instructions sheets were re-written completely to make the whole learning experience a more cohesive whole. The outcomes were considered using performance in the post-laboratory exercises while student opinions were surveyed again.

In both stages two and three, performance in the post-lab exercises offered insight into how well the students understood what they had done. In addition, at the end of stage three, semi-structured interviews were carried out with university teachers to explore the views of university teachers relating to physics laboratories in Libya.

The findings of the third stage and second stage were compared to see what is new in students' perceptions ($N = 106$). The question being explored here was whether the key to the greater success lay in the pre-laboratory exercises on their own or whether the re-written instruction sheets made further major improvements. It was found that there were only very small further improvements, thus confirming that the pre-learning from the pre-laboratory exercises was the key.

The overall conclusions, this study has demonstrated the power and effectiveness of simple pre-laboratory exercises in a typical Libyan university physics course in enhancing understanding in physics. In almost all the survey items, the responses of the students who worked with pre-lab '*with pre-laboratory group*' were significantly more positive than the responses from the students who worked without pre-lab '*without pre-laboratory group*'. Comparing the second stage and the third stage revealed little change, suggesting that the key to the performance improvement as well as the changes in student perceptions was largely due to the pre-laboratory exercises.

Implications of the findings are discussed, especially in the context of education in Libya.

Acknowledgments

Without the help of many people, this study could not have been done. I would like to thank them all.

First of all, I would like to express my deepest gratitude to my supervisor Professor Norman Reid for his support, encouragement, patience, kindness and invaluable guidance through all these years. He was a great supervisor throughout the years of this research and especially during the difficult times of the Libyan revolution. My thanks also goes to Professor Susan Rodrigues for her help during two years and half of this study. I would also like to express my great thanks to my beloved husband Assaid for his support and patience, my son Abdulhaq for his help, my son Altaher and my daughter Jawhara for their support and patience. My thanks goes to all my family in Libya; my mother, sisters and brothers for their support.

My deepest gratitude to Professor Divya Snape for her support and help during this study.

Last but not least, my thanks to all my friends and colleagues in Libya who helped carry out this research. Without their help, this research would not have been possible.

Decleration

I, Saffia Ali Hamed, hereby declare that I am the author of this thesis; that I have consulted all references cited; that I have done all the work recorded by this thesis, and that it has not been previously accepted for a degree.

Signature

I confirm that the conditions of the relevant Ordinance and Regulation have been fulfilled in relation to this thesis.

Prof. Norman Reid

Signature

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Chapter 1

Introduction to the Research Study

> *"Science teaching must take place in a laboratory ...Science simply belongs there as naturally as cooking belongs in the kitchen and gardening in garden...so the teaching of it must involve real contact with those aspects of nature which are to be studied"* *(Solomon, 1980) (p.13).*

1.1 Physics and Laboratory Work

Woolnough (1994) and Osborne *et al.* (1998) spoke of physics as well known in being a conceptually very difficult subject for learners and only suitable for exceptionally able people. In seeking to reduce this problem, laboratory work should be focused on as an essential part of physics courses. Through such practical work, students begin to appreciate how the theory arises from experimentation and how difficult physics concepts can be illustrated. Experimental work can make physics more real and tangible. In addition, the students can also learn experimental design, developing observational and problem-solving skills. Thus, laboratory work can be considered as an essential and integral part of all undergraduate physics courses.

1.2 Objective of the Study

Laboratory work is an integral and important part of undergraduate courses but the reasons for its inclusion vary. Some have emphasised on gaining practical hand and instrument skills. However, there may be more important outcomes for students than making the taught physics real and more tangible. For example, it can help students to observe ways by which physics findings have been widely applied for the benefits of mankind. Laboratory work also offers opportunities for learners to develop skills in thinking, questioning, planning, interpreting data as well as an opportunity to develop group working skills. Above all, physics, like all other sciences, gains its insights by means of experimentation.

In all this, there is a fundamental question. Does the laboratory work currently provided give students any of these key benefits? Previous studies have cast much doubt on this and this study will review potential goals for laboratory courses in physics in higher education as well as exploring the extent to which these goals are being achieved.

Many years ago, Johnstone and Letton (1990) noted that students tend to follow instruction sheets like recipes with little understanding in what they are doing. This can make students feel that the work is pointless and can lead to deteriorating attitudes Johnstone *et al.* (1998). In recent studies (Hanif *et al.*, 2009; Sneddon *et al.*, 2009), the importance of student perceptions has been recognised and measured, offering useful insights from a developed country.

One important outcome from laboratory work is that the students should be able to apply what they have learnt. There is little evidence that this is happening. The idea that understanding can be described in terms of applying knowledge in unfamiliar situations is very relevant to laboratory work. This needs much exploration.

A key finding from the work of Johnstone *et al.* (1994) and Johnstone *et al.* (1998) is that the laboratory almost inevitably generates considerable working memory overload. This study will explore this idea and consider how the cognitive load can be reduced, enabling cognitive capacity to be available for greater understanding.

The way laboratory instruction sheets or manuals have developed into recipes to be followed carefully is well established. The ways by which instruction sheets can be re-cast to enable them to function as clear guides, without prescriptions is not so well established. The danger is that the student is left in considerable uncertainty. This will also be explored.

Finally, most of the research relating to the role and effectiveness of physics laboratory work at higher education level has been carried out in developed countries. This study will look at Libya, a country where educational provision has grown at a quite incredible rate over the past 50 years.

1.3 The Research Aims of This Study

1. Review the current situation in university physics in Libya, focusing on one typical university;
2. From that review, find out the key areas where improvements are needed to enable learning to be more effective;
3. Carry out various adjustments and modifications, all based on past research evidence, and explore what improvements are being achieved;
4. In the light of this, make recommendations of ways by which laboratory work in physics in higher education institutions in Libya can be enhanced.

The work will be conducted in three stages which will be described later in this thesis.

1.4 Study Overview

This research starts by exploring the physics laboratory experience with students at University level and considering student perceptions of university physics laboratories in Libya. At the same time, the views of university teachers related to university physics laboratories in Libya were also explored. The overall aim is to establish ways by which the student experience might be enhanced and to examine the benefits in terms of making the laboratory experience more effective for understanding physics for students in Libya. The developments introduced and how they were evaluated are described.

One key aim in all learning stages is the development of understanding, reflected in an ability to apply the knowledge gained. Thus, chapter two focuses first on the description of learning, addressing cognitive models of students' learning and the way humans organise information.

This is narrowed down in chapter three which focuses on learning in the laboratory in higher education. Learning in higher education will be considered briefly, followed by a historical review about laboratory work. The reasons for undertaking laboratory work will be considered along with a review of possible aims for it. Finally, the various main styles of laboratories will be reviewed.

Chapter four outlines the most recent findings from information processing which shows how learning takes place. This is of direct importance in laboratory learning where there is an information-rich environment, making cognitive overload a real problem.

Learning is not simply a cognitive activity. Learners bring attitudes to their studies and attitude develops from their studies. In higher education, the work of Perry is seminal (Perry, 1999) and chapter five will cover different aspects of the Perry scheme. It will outline the original scheme and discuss the adaptations of it as well as strategies which have been suggested to help students to grow intellectually. Student perceptions of learning, as Perry described them, will also be discussed in the light of other contributions from the literature. Finally, the Perry scheme of intellectual development will be discussed critically.

Chapter six outlines the method and techniques which were employed to gather and analyse the data. The data obtained are then discussed in chapter seven, eight, nine, and ten.

Chapter seven contains the data from the questionnaires in the first stage and these will be summarised and discussed. This involves the questionnaires which were used with first semester students at the beginning of their study at university to investigate their perceptions of physics laboratories in school, as well as the questionnaires used at the end of the first semester to establish an overview of their perception of physics laboratory work at university in order to identify areas where support is needed.

In the second stage, a new approach was developed in an attempt to make the laboratory experience more effective for understanding. Chapter eight contains the data from this stage describing some steps that were taken to address some of the problems identified in the first stage for university students at Sebha University. The outcomes from these changes, where applied to a physics laboratory in Libya, will be presented and discussed. Some gender issues will also be explored.

In the light of the findings from the second stage, the third stage carries through the development to a greater extent. This is the focus of chapter nine. The outcomes of these changes will be evaluated critically in terms of student perceptions and student achievements, seen in terms of being able to apply the ideas learnt in the laboratory in other situations. Again, gender issues will be addressed.

In stage two, various changes were introduced and described. In stage three, further changes were involved. Chapter ten now compares the findings from stages two and three to see if evidence can be found about the relative importance of these various changes.

Finally, chapter eleven summarises the findings of the entire study, links these findings to previous work and suggests some areas where further enquiry in needed. It is hoped that this study will offer insights into the problem of laboratory work in Libya so that it will be possible to recommend changes which might reduce the current problems.

Chapter 2

Learning and Cognitive Models

2.1 Introduction

Before considering the theme of this chapter, the way the literature was approached is now described briefly.

University laboratory courses are designed so that students will learn and the literature on learning and, specifically, learning in the laboratory is discussed. Much of the key work that underpins this study was first explored by Professor Alex H Johnstone and his team of researchers. Their extensive publications offered a useful starting point. They developed the concept of the pre-laboratory as applied to university laboratory work and explored its effectiveness in both chemistry and physics. The key feature of this work was that the effectiveness of the pre-laboratory was predicted on the basis of many previous studies and they found that the key factor in this is the known limitation of working memory capacity.

In following through this work, it became apparent that science education has been strongly influenced by the research studies coming from John Piaget, David Ausubel and Jerome Bruner. Indeed, all of them specifically addressed learning issues related to conceptual learning in the sciences. In the past two or three decades, the whole understanding of conceptual learning has been revolutionised by the insights from information processing and the work of Alan D Baddeley and Alex H Johnstone stand out in this area. Indeed, the specialised science education journals show the strong influence of these major contributions. Thus, an entire journal issue (e.g. Research in Science and Technological Education Volume 27(2), in 2009) was noted to be centred on the limitations of working memory as it affected learning in conceptual areas like the sciences.

Of course, all learning is affected by student attitudes and learning in the laboratory is no exception. In looking at the attitudinal aspects of learning which play a major role in science education, the work of the Harvard psychologist William G Perry has offered a model which has been used extensively in interpreting attitude development (and other areas) in science education degrees. This offered another major strand of research which is reviewed here.

In addition, 'Google scholar' searches, using phrases like 'physical laboratory learning', 'Higher education physics learning', widened the range of references.

The review of literature now starts by considering cognitive models of learning.

In order to understand what is happening in the classroom and to improve our teaching to make the student reach functional understanding, this chapter focuses first on the description of learning, then it will address cognitive models of students learning, and the way humans organise information. The phrase '*functional understanding'* has been used. And it implies understanding that is sufficient to be used. Indeed, if a person genuinely understands what has been learnt, then that person can apply that knowledge in a novel situation with some prospect of success. This has to be a goal for all education for knowledge that cannot be used is of little value.

Furthermore, to have knowledge and skills does not necessarily mean understanding. For example, students might know through rote learning, facts and formulae such as $V = RI$ and the fact that the formula is called Ohm's law, but this does not mean that Ohm's law is understood. It is necessary that the learner should explain what the formula means, what the symbols V, R, I, refer to, what is the effect of change R on I, what is the importance of this law in electricity to show a good understanding of Ohm's law.

According to Skemp (1976, 1987) understanding can be divided into two types:

I. **Relational understanding**: this relates to knowing what and why.
II. **Instrumental understanding**: which refers to ability to apply rules but without knowing the reasons, almost doing without understanding.

Carpenter and Lehrer (1999) describe understanding (in mathematics and science) in terms of mental activity that contributes to the development of understanding and not as static attributes of a person's knowledge. They suggest the following forms of mental activity:

I. Constructing relationships.
II. Extending and applying mathematics and scientific knowledge.
III. Reflecting about experiences.
IV. Articulating what one knows.
V. Making mathematics and scientific knowledge one's own.

2.2 Learning

It is difficult to summarise learning in a single phrase which will encompass all situations; indeed, all kinds of learning start from birth. Gagné (1970) stated that "learning is a change in human disposition or capability, which can be retained, and which is not simply ascribable to the process of growth".

Reid (2008) describes learning as a process that leads to any change in behaviour not explainable simply by development. Hamachek (1995) grasps that a change in a person's behaviour does not only refer to outcomes that are manifestly observable but also to attitudes, feelings, and intellectual processes that may not be so obvious. The change in behaviour should lead the learner to be able to use this gained knowledge in unfamiliar situations. However, learning is not just transferring knowledge from the teacher to student. Psychologists describe learning as a change in the individual's behaviour arising from experience.

In addition, Gibbs (1992), specifically in a university setting, expanded the idea of learning being seen in terms of changes in behaviour. He noted that the learner has the ability to exercise intellectual and creative powers, understand, judge, solve problems and communicate.

2.3 Aspects of learning

For centuries, there was a strong emphasis on education being seen as the transfer of information from the head of the teacher into the head of the learner. This is captured well, in caricature form, in the work of Charles Dickens as illustrated in Figure 2.1.

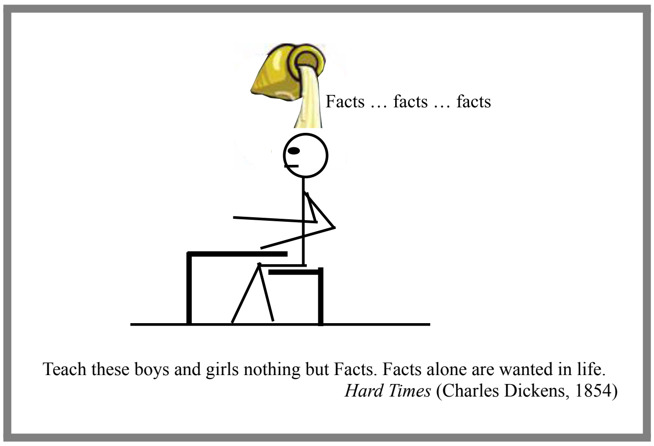


Figure (2.1): *Caricature of Learning*

Today, education researchers need to focus on the quality of the learning processes rather than the specific content or knowledge of curriculum transmitted (Zoller, 1993, 2000; Johnstone *et al.*, 1994).

Thus, Ramsden (1992) has emphasised the strategies that could improve teaching and learning. Garrison *et al.* (1995) draw attention to two fundamental approaches learning:

- Deep approach.
- Surface approach.

The deep approach focuses on understanding and relates new ideas to previous knowledge. In addition, the deep approach relates the concept to every-day practice, and evidence to conclusions. Furthermore, the deep approach examines the logic of an argument (Entwistle, 1987).

The surface approach focuses on the memorisation and reproduction of information. This is seen as very important for assessments where, sadly, the rewards often come for information reproduced. The surface approach often fails to distinguish principles from examples and sees tasks as an external imposition. Thus, the surface approach not only concentrates on the disparate elements of knowledge with little integration of ideas but also does not focus on purpose or strategies (Entwistle, 1987).

Gibbs (1994) argues that the outcomes from a surface approach are very poor as well as generating little understanding. Moreover, there will be short-term recall of the information, and then poor grades if the assessment favours a deep approach. However, if the assessments are mainly based on factual recall of knowledge and well-rehearsed algorithms, the surface approach learner will bring adequate rewards although a deep approach leads to good understanding, as well as long term recall and better grades (Gibbs, 1994).

The deep approach first described by Entwistle has some similarities with the description of understanding reflecting the ability to use information in novel situations. That ability might be seen as the evidence of the deep approach. However, Entwistle and those who have developed his ideas are well aware that, in higher education, students have different motives for reproducing information. For some, the main aim is to gain a pass with the minimum of effort. This may well lead to a surface approach. Thus, the ideas of deep and surface learning carry with them attitudes to the entire learning process.

Noting this, Ramsden (1992) pointed out that an individual could use both approaches at the same time even though there is a preference for one approach over the other. For example, when a student simply needs to repeat factual knowledge, a surface approach is adequate while, in the case of solving problems, the student needs to use a deep approach.

Entwistle and Ramsden (1983) suggest another approach to learning. This approach is called the strategic or achieving approach and seeks to obtain best possible grades through organised study strategies, effective time management and alertness to assessment methods. It is one matter to describe these approaches which have been observed to be adopted by learners in higher education. It is much more difficult to develop strategies which encourage more deep learning, for this involves attitude changes as well. Entwistle (2000) summarised the approaches of learning in this diagram below:

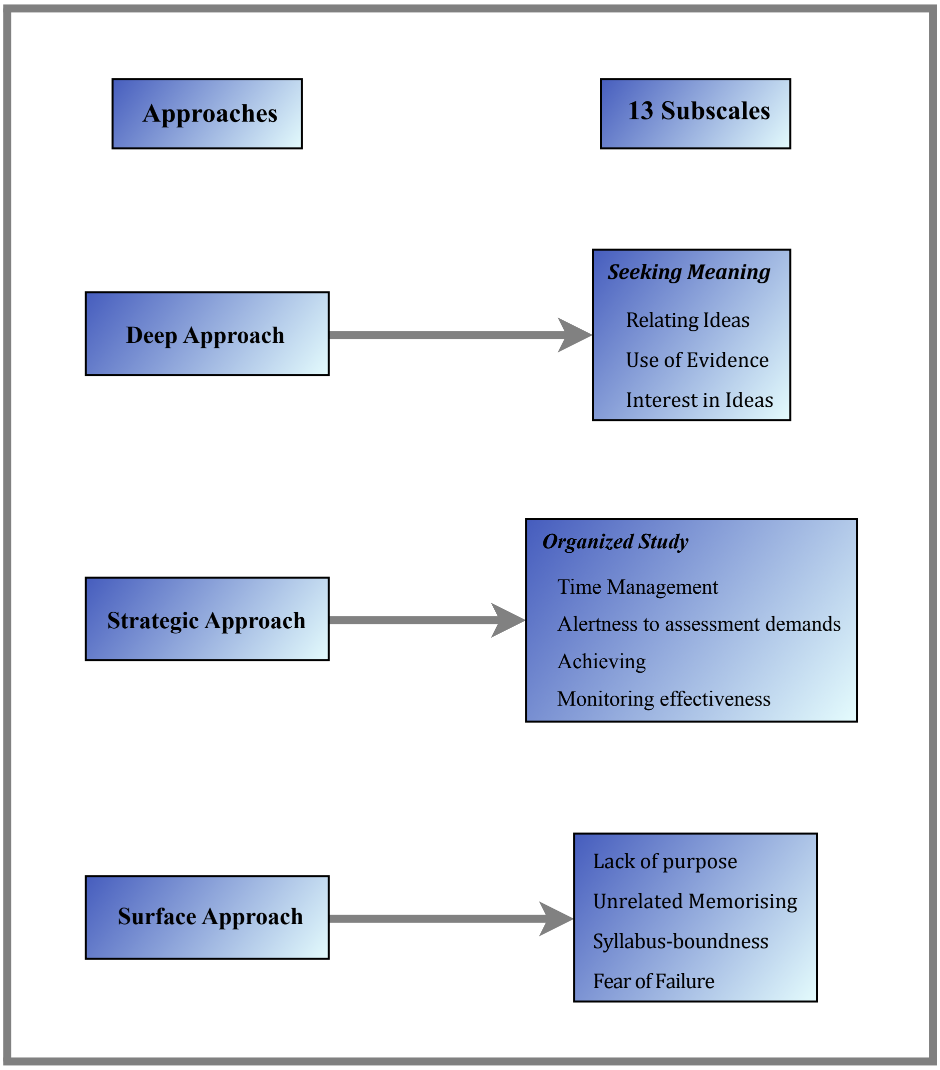


Figure (2.2): *ASSISST inventories, approaches to learning (Entwistle, 2000)*

2.4 Models of Cognitive Development

There have been many attempts to describe the human learning process. Among the most important for teachers are those that look at the growth of the human mind and which provide clear and explicit instruction and models.

Cognitive models seek to investigate how learners acquire, process, store and use information. One model developed from research is Piaget's Model of cognitive development.

2.4.1 Piaget's Model of Cognitive Development

Piaget was born in Neuchatel, Switzerland, on 9^{th} of August 1896, and died in Geneva on 16^{th} of September 1980. Jean Piaget moved from biology to philosophy and eventually to psychology. This moving from biology to psychology influenced his beliefs in his theory of intellectual development. Thus, he saw the child as an organism, adapting to its environment.

He started to focus his interest on the idea of how children's thinking developed. He observed that young children's answers were qualitatively different by comparing their answers with older children (Bliss, 1995). He suggested, that young children are not stupid, but, instead, they answer the questions differently from the older ones, because they think differently (Egan, 1983).

Piaget's life was devoted to the search for mechanism of biological adaptation on the one hand, and the analysis of logical thought on the other hand. Adaptation is the process that occurs in order to organise thinking in response to the environment. Adaptation plays a central role in Piaget's theory, perhaps the most basic of all Piaget's ideas.

In order to explain children's adaptation to environment, Piaget used features of biological adaptation and created his own distinctive terminology as discussed below:

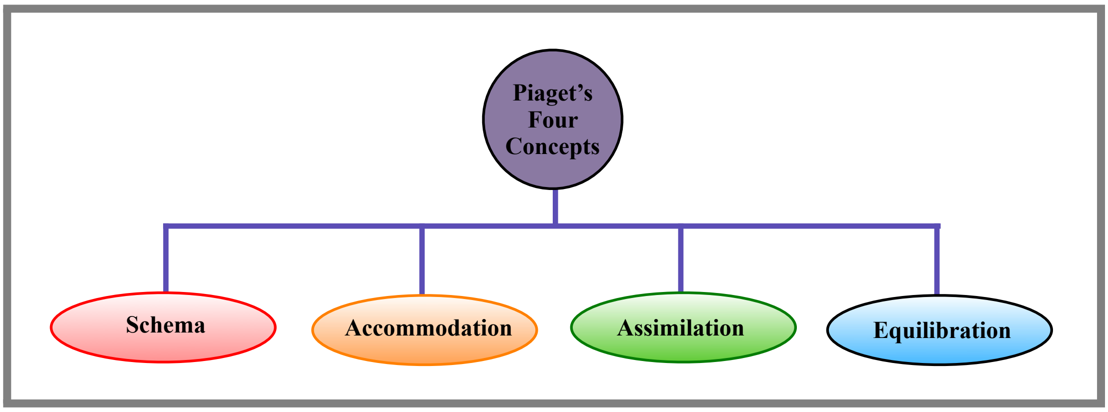


Figure (2.3): *Piaget four concepts*

Schemata: according to Piaget, schemata are the simplest organised patterns or units of action or thought that help to make sense of our interactions with the world. Schemata can be likened to files in which we store information. Piaget believed that thought is internalised action. Individuals interact with and explore the environment around them, and it is this physical interaction that becomes internalised to create thought.

Piaget suggested that, at birth, schemata are reflexive in nature, and also these schemata can be inferred from simple reflex motor activities such as sucking and grasping. With the growth of the child, the schemata become more differentiated, less sensory, and steadily forming an increasingly complex network.

The schemata of adults evolve from those of children through adaptation and organisation. The schemata become internalised and are organised into complex thought structures. Then, the abilities to comprehend and manipulate abstract verbal symbols and relationships and to employ abstract classificatory schemata is also found to increase.

Assimilation and Accommodation: Assimilation is a cognitive process: taking in new information and trying to fit this information into existing Schemata, or responding to the environment in terms of previously learnt patterns of behaviour or schemata. Accommodation means modifying existing Schemata or the creation of new ones to fit the new information, or responding to the environment in new manner. Piaget observed the equilibrium or balance between assimilation and accommodation as necessary for cognitive growth and development. Moreover, when existence schemata cannot deal with new experience then there will be dis-equilibrium.

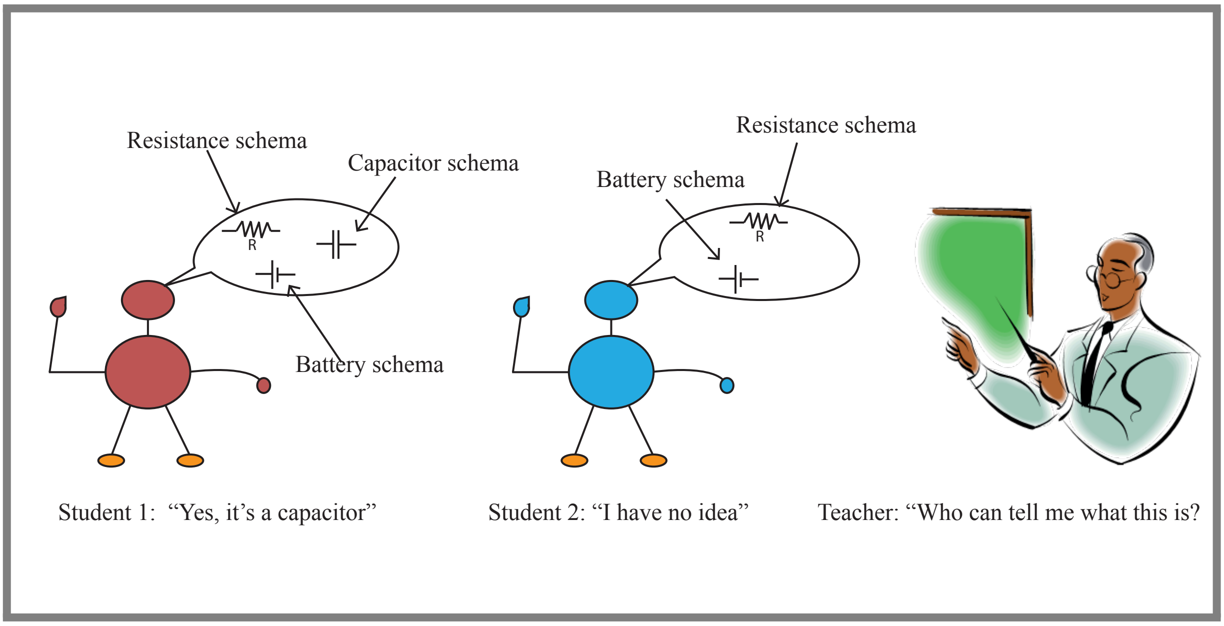


Figure (2.4): *An illustration of the processes of Accommodation and Assimilation*

2.4.1.1 Piaget's Cognitive Stages

Piaget described the stages of cognitive development he observed in the following way (Table 2.1).

Table (2.1): *Piaget's cognitive stages (Atkinson* et al.*, 1993)*

Stages of intellectual development	**Description**
Sensorimotor (birth to 2 years)	Differentiates self from objects. Recognises self as agent of action and begins to act intentionally. Achieves object performance, realising that things exist even when no longer present to the senses.
Pre-operational (2-7 years)	Learns to use language and to represent objects by images and words. Thinking is still egocentric with difficulty in seeing the viewpoint of others. Classifies objects by a single feature e.g. colour.
Concrete operational (7-11 years)	Can think logically about objects and events. Achieves conservation of number (age 6), mass (age 7) and weight (age 9). Can classify objects according to several features and can order them in series along a single dimension.
Formal operational (11 years on)	Can think logically about abstract proportions. Can test hypothesis systematically. Becomes concerned with the hypothetical, the future, and ideological problems.

Pre-operational stage (2-7): As indicated in Table 2.1, the children represent objects by image and words, they describe the group of things by single feature like colour or shape not both together. Nolen-Hoeksema *et al.* (2009) referred to that during the pre-operational stage: "*the child does not yet comprehend certain rules or operations; an operation is a mental routine for separating, combining, and otherwise transforming information in logical manner*".For example, the same quantity of juice is poured into two glasses where the two glasses have different shapes. One glass is short and fat while the other is tall and thin. When asked about which glass has more juice, the young child will say that the tall contains more juice. They do not understand that the juice has the same volume, when it is poured from the tall glass to short one , as in Figure 2.5. As a result, the children at this stage have not attained understanding of conservation. (Nolen-Hoeksema *et al.*, 2009).

Although the young child cannot grasp the concept of volume, they understand the word 'more' in terms of one dimension - height. There is an issue here: what is meant by the word 'more' - more in height, more in width, more in volume?

For example, suppose you arrange two rows of blocks in such a way that a row of 5 blocks is longer than a row of 7 blocks. Pre-operational children can generally

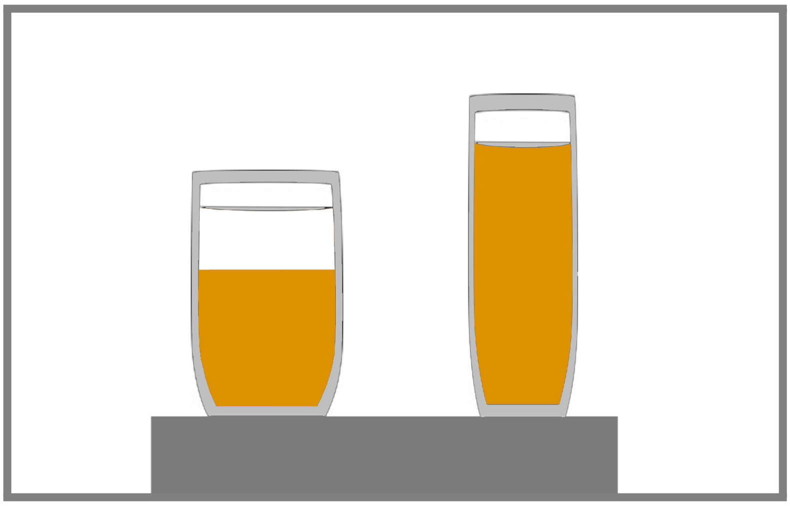


Figure (2.5): *The idea of conservation with children*

count the blocks in each row and tell you the number contained in each. However, if you ask which row has more, they will likely say that it is the one that makes the longer line, because they cannot simultaneously focus on both the length and the number. The ability to solve this and other “conservation” problems signals the transition to the next stage

Furthermore, according to Piaget, there is another feature of the pre-operational stage which is ego-centrism; the children at this stage believe that every one also perceives the environment the same way they do (Piaget, 1950). Piaget believed that ego-centrism explains the rigidity of pre-operational thought, because young children cannot appreciate points of view other than their own.

Operational stage (7-11): The important characteristic of the operational stage is that the children start to master the various conservation concepts as well as developing the skills to perform logical manipulations. Thus, if you give a child at this stage different objects with different height or different weight, they can order them on the basis of one dimension.

At this stage, Piaget considered that the children can form a mental representation of a series of actions. Thus, the child can readily draw a map of the route. Piaget described this stage as the concrete operational stage. It is important to note that the development of logical thought and ideas of conservation are important and essential to understand the ideas of sciences such as physics and chemistry. It is, therefore, unlikely that teaching such subjects before age 11 will lead to much meaningful learning (Sutherland, 1982).

Formal operational (11 years onwards): From approximately age 11, the learners are starting to develop the skills of adult modes of learning. Thus, the person is beginning to reason in symbolic terms. Of course, this does not happen overnight. Piaget observed that cognitive development continued to about age 16. By this age, the person is capable of working in the abstract and hypothetical.

Piaget's formal operational thinking is hypothetico-deductive. The adolescent can conceive of a new idea, try it out in his head and then test it. Thus, deduction can be employed at this stage. The young teenager starts to be able to deduce an implication from a general principle. This means that, in physics, formulae can be understood and applied. In mathematics, a follow-up proposition can be deduced from a general proposition. In addition, the adolescent becomes capable of drawing the necessary conclusions from truths which are merely possible.

In addition, in the formal operations, various elements in a problem interact with each other. To illustrate this idea, in the hydraulic press, which is shown in the Figure 2.6 below, the intuitive thinker knows the left-hand side will go down under the weight and the right side will go up. The concrete operational thinker adds the compensatory element: the left side is wider than the right, so the left will sink less than the right will rise. On the other hand, the formal operational thinker is able to calculate the distances the liquid will move up or down the cylinder using the appropriate formula.

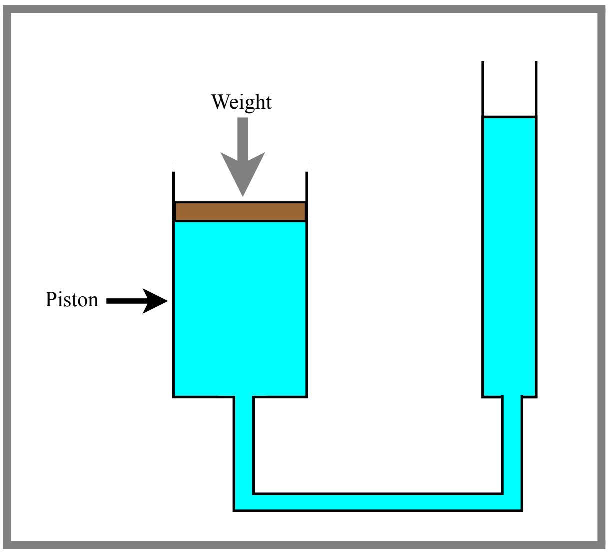


Figure (2.6): *An illustration of formal operational thinking.(Sutherland, 1992, page 22)*

2.4.1.2 Criticism of Piaget's Model of Cognitive Development

Numerous criticisms have been raised about Piaget's work and these can be summarised under the following headings:

1. Piaget research sample was not sufficiently large, and he did not pay enough attention to statistical significance (Ausubel *et al.*, 1978).
2. Donaldson (1978) expressed concern about the way in which Piaget asked children questions in experimental situations; also she did not accept the rigidity of the proposed stages.
3. Piaget theory takes little account of the importance of social interaction and language in child development. Piaget argued that the egocentric speech of children goes away with maturity. On the contrary, Vygotsky (1986) argued that the children's mind is inherently social in nature and so speech moves from communicative social to inner egocentric.
4. Sutherland (1992) summarised the criticisms of aspects of Piaget's theory in terms of:

- Sensorimotor period: Piaget did not take into account the need for motivation in order for children to search, or the fact that very young infants may not have the knowledge of how to search.
- Concrete Operational period: Piaget did not take into account the importance of creativity and social interaction.
- Piaget largely ignored individual difference, this is meant in terms of individual differences in personality, gender, intelligence and other factors that affect the ability to progress cognitively.
- Piaget's clinical interview for its lack of scientific rigour by different scholars.

In conclusion, Piaget is believed to be one of the first to advocate forcefully, with extensive supporting evidence, the notion that children construct their own knowledge and that this knowledge is different in kind from adults. He suggested that the constructed knowledge is "evolving and changing" (Bliss, 1995). Over time, in Piaget's world the child is perceived as an organism, affected by the environment where the child grows, adapting to its surroundings, absorbing (assimilating) what was required for growth and necessarily changing its behaviour (accommodation) at the same time (Wadsworth, 1989).

Wadsworth (1984) perceives that Piaget's general hypothesis is simply that cognitive development is a coherent process of successive qualitative changes of cognitive structures (schemata). Furthermore, Ausubel *et al.* (1980) notes that the importance of Piaget's stages ideas are the fixed order of succession. However, the actual ages involved may vary slightly from child to child.

Miller (1993) sees Piaget as a psychologist who established the basics for modern education thought and he had profound impact on educational practice and research. This is true for the impact of Piaget's ideas was very considerable in the 1960s and 1970s. His ideas have influenced the primary and early secondary schools curricula in many countries (Bliss, 1995). In fact, Piaget's theory can be considered to have long lasting effects on educators compared to other theories of the time.

The key significance for today can be listed:

- The natural way for learners is to try to make sense of the world around. In doing this, the learner may develop wrong understandings but these develop naturally with time;
- The young child has not yet developed the thinking skills of the adult.

The significance of this is a recognition that memorisation of information (the Victorian idea exemplified by the pouring of facts into the young learners head) is not the natural way of learning. Learning is a '*sense-making'* process. This has huge implications for learning in the sciences where, too often, the memorisation of information has become too dominant. There are also large implications for the sciences in terms of not introducing ideas at too young an age before the necessary mental structures are in place. This can often contribute to the generation of misconceptions where the learner is trying to make sense and makes errors simply because the ideas have been introduced before the necessary mental structures and underlying ideas are in place.

All of this has considerable importance in laboratory work. The natural process of meaning-making may be hindered by the actual process of seeking to conduct the experiments in line with the instructions. If laboratory work is to make a contribution to understanding, then the way the laboratory work is structured must allow for the need to make sense of what is being undertaken.

2.4.2 Ausubel's Learning Model

David Ausubel was a cognitive psychologist exploring learning. Ausubel (1968) focused on both the presentational methods of teaching and the acquisition of knowledge. He made a major contribution to learning and studied and described the conditions that lead to what he called 'meaningful learning', Ausubel put forward the model of learning which distinguishes meaningful learning from rote learning. His model stresses two important aspects (Novak, 1978):

1. How individuals learn large amounts of information meaningfully from verbal / textual presentations in a formal setting.
2. The significance of an individual's prior knowledge in influencing learning.

Ausubel and Robinson (1969) classify the types of learning into two main categories, rote and meaningful learning; In addition, he identified learning according to the ways of presenting information, reception and discovery learning.

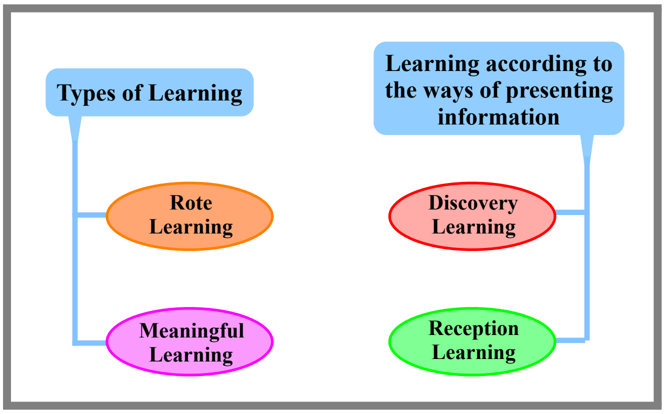


Figure (2.7): *Ausubel's Types of Learning*

One of Ausubel's great contributions was to separate the ideas of meaningful-rote learning from the reception-discovery learning. Despite his clarification, there is still confusion with some wrongly considering that teacher centred reception learning hindering the possibility of meaningful learning. His findings are illustrated in Figure 2.8.

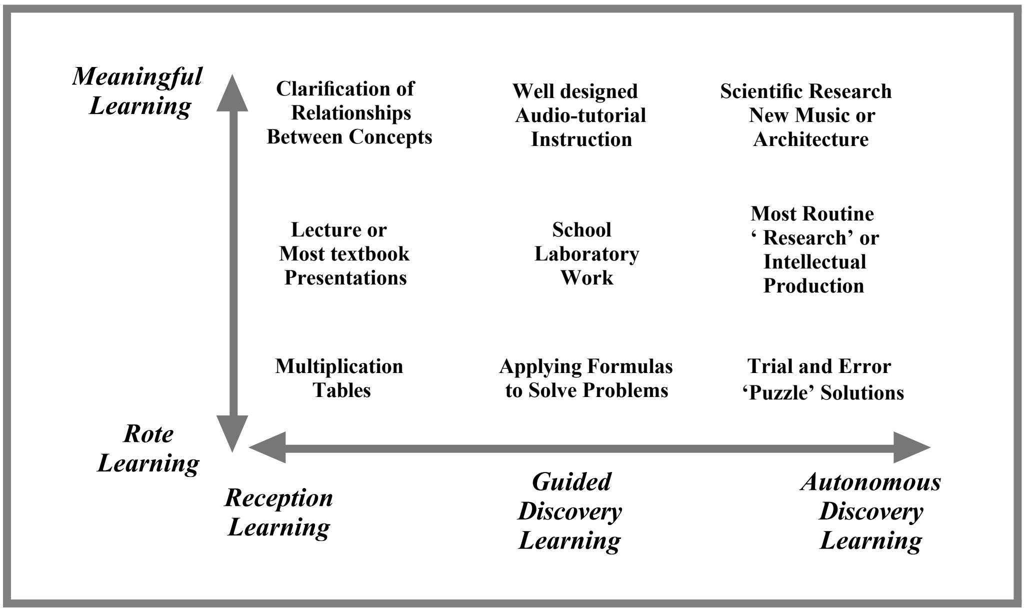


Figure (2.8): *Ausubel's Model*

One of his other major contributions was to observe the way previous knowledge influenced new learning. This is seen in his statement:

> *"If I had to reduce all educational psychology to just one principle, I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." (Ausubel, 1968)*

Ausubel (1968) pointed out that the meaningful learning would happen when new concepts can be related to the pre-existing concepts in learning cognitive structure. According to Ausubel *et al.* (1978), meaningful learning could happen if the following criteria are met:

- "that the learning material itself can be non-arbitrary (plausibly, sensibly, and non-randomly) and substantively (non-verbatimly) related to an appropriate cognitive structure (possesses "*logical meaning*").
- That the particular learner's cognitive structure contains relevant anchoring idea(s) to which the new material can be related.

- The interaction between potentially new meaning and relevant ideas in learner's cognitive structure gives rise to actual or psychological meanings. Because each learner's cognitive structure is unique, all acquired new meanings are perforce themselves unique"

On the other hand, Ausubel and Robinson (1969) found that rote learning could take place under these conditions:

- The information or the material to be learnt lacks the logical meaningfulness;
- The learner had not enough skill to enable him or her to learn meaningfully;
- When the learner does not possess the appropriate schemata for construction of new knowledge.

Hence, it can be said that rote learning is closely associated with the surface learning approach, while meaningful learning tends to relate to the deep learning approach. Of course, rote learning is not always undesirable: learning mathematical tables, the alphabet or a foreign language will all find rote learning important.

Reception Learning: Larochelle *et al.* (1998) defined reception learning as very much teacher-centred where the information is presented in an understandable form to the learners during the lesson. For this reason, the pupils are not engaged in any tenable independent discovery learning since all they need to know about the material to be learnt is given to them by the teacher. Accordingly, the assessment of this way of acquiring knowledge requires that pupils have to recall only that which they have been taught in the specific lesson. Of course, while this is often true, it is still possible for a teacher to direct discovery learning.

On the contrary, discovery learning requires learners to discover the main content of topic presented during a lesson. However, this may be an over-simplified picture. It is possible for a lesson topic to be planned by the teacher who then allows the learners to make progress by means of discovery. Thus, each learner will rearrange, combine and integrate the new knowledge and information in different ways by using their existing knowledge to reach meaningful learning. Of course, each individual may handle the information in different ways, with different interpretation of incoming information. Bruner, the leader of discovery learning, argued that meaningful learning could take place by encouraging the students to discover things on their own (Good & Brophy, 1990). However, Ausubel argued that discovery learning is ineffective much of the time and regarded this type of learning as largely a waste of time (Ausubel, 1968).

Thus, Ausubel (1968) was very hesitant about the value of discovery learning and anticipated reception learning to be more efficient and effective. Despite this, Ausubel *et al.* (1978) stated that both discovery and reception learning can be categorised to be either meaningful or rote learning depending on what happens after the material to be learnt is presented to the learner. He argues that reception learning can be made meaningful if the material to be learnt is presented conscientiously (see Figure 2.9).

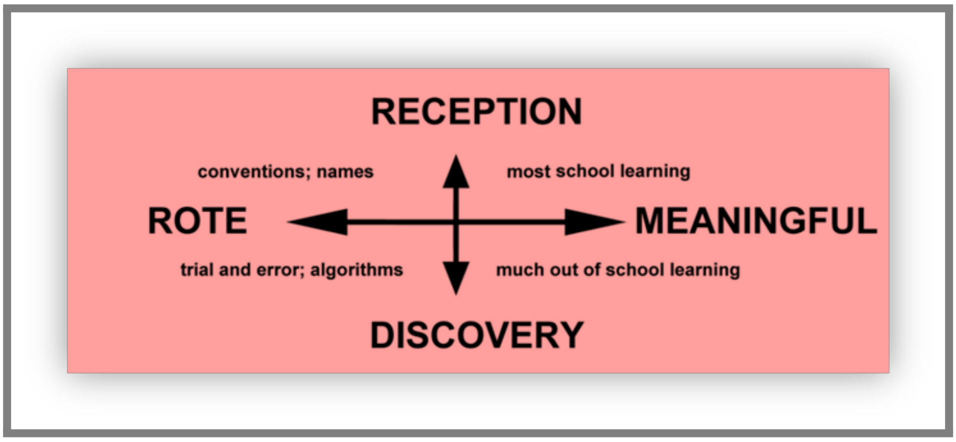


Figure (2.9): *Dimensions of Learning*

The concept of Subsumption: It is a key concept in Ausubel and Robinson (1969) assimilation theory of learning, and what the learner already knows is the most important single influencing learning. Bringing this together, Ausubel argues that meaningful learning does not result in new knowledge as simply added to concepts. Instead, the new knowledge interacts with and assimilates the existing relevant concept through what he called anchoring concepts. Consequently, an altered form of both the new knowledge and anchoring concept emerges.

Ausubel *et al.* (1978) describes the anchoring concepts as subsumers. He further adds that the process of its effectiveness depends on the growing differentiation and integration structures. Accordingly, a learner whose subsumption process is well-developed can be expected to solve more complex problems than a learner whose subsumption is poorly developed.

Advance organisers: Ausubel (1968) proposes the idea of advance organisers. Such organisers link effectively the new information or new knowledge with the anchoring concepts in the learner's cognitive structure. It could also be depicted as a kind of conceptual bridge between the new information and the learner's current knowledge. In addition to the above, he proposes that advance organisers be used in the following cases:

1. The case where the learner does not possess the appropriate subsumers to relate to the new material.
2. The case where the learner does possess the relevant subsumer but they are not really developed, such that they are not likely to be called upon to relate to the new material.

In fact, Novak (1978) points out that the advance organiser will not function if the new material to be learnt has no relevant concepts in the learner's cognitive structure.

To sum up, Ausubel emphasised that the existing knowledge is a prerequisite for meaningful acquisition of knowledge to occur. Ausubel does not associate learning to the age of the learner as is the case with Piaget's model. He believes that it is not the intellectual process that distinguishes a child's cognitive ability from that of an adult, but the amount of knowledge they both possess.

In considering laboratory learning in physics, Ausubel's findings are important. The student comes into the laboratory with previous knowledge and experience. What faces the student may be new. However, this has to be related to what he/she already holds in long-term memory. If the links between what is already held and the new experiences facing him/her are not made overtly, it may prove difficult to link new ideas to old. Increased understanding may then not occur. This relates to what Johnstone and Wham (1982) found and underpins the need for preparing the mind for learning, an idea that led to the development of pre-learning experiences in relation to university laboratory work see (see Carnduff & Reid, 2003).

2.4.3 Bruner and the Discovery Learning Model

Bruner has made a profound contribution to the development of curriculum theory. Bruner was greatly inspired by Vygotsky (1962) idea that thought and language were instruments for planning and carrying out actions. According to Bruner, the child's cognitive development can be enhanced significantly by careful curriculum design and strategic teaching. Bruner is famous and respected for the statement that "*any subject could be taught to anybody at any stage in some form that was honest*" (Bruner, 1963). On the other hand, critics believe that discovery learning is so inefficient and so difficult to organise successfully that other methods are preferable. It could be especially true for lower-ability students, because this method may cause too many demands on these students, because they lack the background knowledge and problem-solving skills (Rowell & Dawson, 1988). Indeed, in many areas, this proves to be very difficult to use this method, and it is unlikely that students can make a discovery in a few hours which in reality took the best intellects many centuries to develop.

In the 1960s and 1970s, developments in science curricula in some countries were influenced by Bruner's ideas. This probably arose from incorrect logic. It was assumed that, as the sciences make their progress by means of experimental discoveries, the teaching of the sciences should follow a similar approach. However, the methods of the sciences are not necessarily related in any way to the way the sciences should be taught.

New school curricula in Scotland in chemistry and physics (Curriculum Papers 490, 1962; Curriculum Papers 512, 1962) involved extensive practical work which was apparently based on a general principle of guided discovery, and this curriculum proved to be highly successful. The '*success'* of these curricula was reflected in high uptake numbers (Scottish Qualification Authority, Annual Reports, 1962 to 2011). The key was '*guided'*. The teachers were directing the discovery process. However, countries which structured their curricula in terms of discovery learning were much less successful (e.g. Nuffield science in England) in terms of numbers uptakes. However, it is possible that there were gains in levels of understanding although there is a lack of clear evidence.

The key feature for success seems to lie in the word, '*guided'*, but the amount of guidance needed is not exactly known. Reid (2006) notes that there was more or less no "*Swing from Science*" in the 1960s (Dainton, 1968). Indeed, physics and chemistry remain to this day in Scotland as the two of the three most popular elective subjects (the third being biology) at the level of entry to Higher Education.

Bruner (1966) built his model of discovery learning on the assumption that learning is an active, social process in which learners generate new knowledge or concepts based upon their prior knowledge. In the learning of science and mathematics, the learner selects and modifies information, formulates hypotheses and makes decisions, all the time relying on existing cognitive structures to do so, and the cognitive structures are crucial for the provision of meaning to experiences, and also responsible for the reorganisation of the selected information within the specific content domain. According to Bruner (1966), knowledge development should take place in the form of "skill integration".

2.4.3.1 Stages of Cognitive Development

Rejecting the age-stage ideas of Piaget, Bruner (1986) suggested stages called representations:

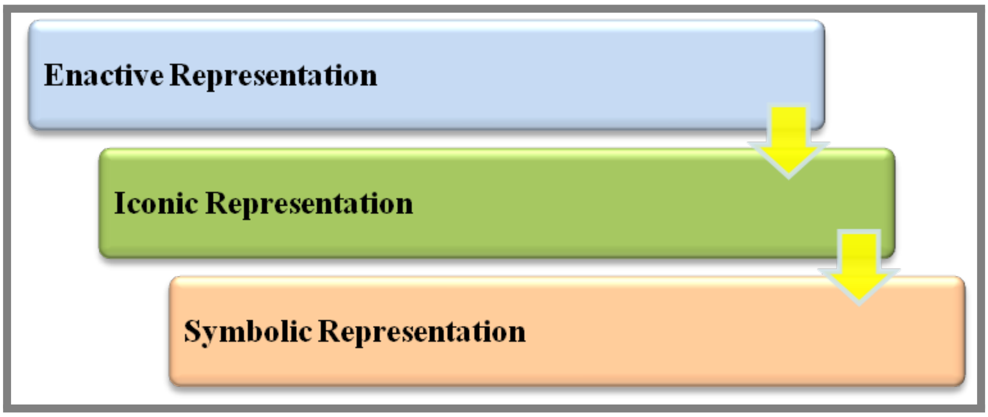


Figure (2.10): *Stages of Bruner Theory*

The features of his theory of instruction are:

1. The student's predisposition towards learning: cultural, motivational, relation between students and instructor (could be parent or teacher), preschool environment, all these could be factors that may influence children predisposition to learn.
2. The structure of the body of knowledge to be learnt has to be readily understood, or comprehended by the learner. According to Bruner (1966) "any idea or problem or body of knowledge can be presented in a form simple enough so that any particular learner can understand it in a recognizable form". Furthermore, Bruner's idea can be used with any scope of knowledge for example, in physics in the topic of gravity can be presented in three ways or models: by a set of action for Enactive Representation, by set of images or graphing that stand for concepts for Iconic Representation, and by as set of symbolic or logical statements for Symbolic Representation. The same thing could be done in other fields like biology, or chemistry.

3. The most effective sequences in which to present material: Bruner (1966) stated that “instruction consists of leading the learner through a sequence of statement and restatements of problem or body of knowledge that increase the learner ability to grasp, and transfer what he is learning”. Accordingly, there is a regular sequence for all learners because each learner has different past experiences and different development stages. However, the general sequence of presenting material usually follows the intellectual development and moves “from enactive through iconic to symbolic representation of the world”. (Bruner, 1966). However, these seem to move somewhat from discovery learning, involving much teacher direction.
4. The final point of Bruner’s theory is that the nature and pacing of rewards and punishments should be specified. Bruner points out that learning depends upon knowledge of results which can be used for correction. Feedback to the learner is important to the development of knowledge. The teacher can provide a vital link to the learner in feedback at first, as well helping the learner to develop techniques to obtain feedback on his or her own “make the learner or problem solver self-sufficient” (Bruner, 1966).

Overall, Bruner emphasises the idea that education is process of discovery. He argued that, when the information or knowledge is gained by personal discovery, it will be better understood. Furthermore, he advocated that, when the students were allowed to pursue concepts on their own, their understanding will be better, and the teacher in this situation will guide the students when necessary, so that students would progressively build their own knowledge base, rather than taught (Bruner, 1966).

The Bruner representations are parallelled by Johnstone’s macro, micro, and symbolic representations as seen in Figure 2.11 (Johnstone, 2000).

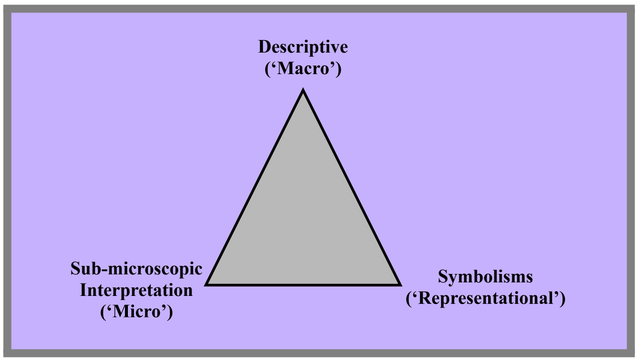


Figure (2.11): *Physics Triangle*

On the macro level, this level related to enactive mode of Bruner representation which he considers knowing some aspect of reality without the use of imagery, i.e. knowing how to do something (for example, a child knows how to ride a bike). The second level, according to Johnstone, is sub-micro. This is an invisible level in which an attempt is made to give mental pictures to explain or describe what is observed at the macro level. The 2nd level is related to the iconic mode of Bruner's representation which is based upon internal visual imagery that is governed by principles and techniques such as filling in, completing and extrapolating knowledge from available sensory experience to make transformations in perceptual organisation. The final level according to Johnstone is the symbolic (representational) level in which the student tries to represent observations by formulae, mathematics manipulations and drawing graphs or diagrams. This level relates to the symbolic mode of Bruner's representation where the person uses symbolic representations (mathematics and language)

2.4.3.2 Summary and Comment

Bruner (1966) argues for learning by discovery while Ausubel (1968) has clearly separated the discovery-reception axis of learning from the meaningful-rote axis. Bruner advocates discovery learning as a general teaching method. By using this type of teaching method, the student needs to collect, link, and construct his or her cognitive structure by himself. By contrast, Ausubel sees learning being most effective and efficient, when the materials are structured and directed by the teacher.

Schneider and Shiffrin (1977) suggested that schemata allowed many elements to be treated as a single element in working memory and this led to Tuovinen and Sweller (1999) suggesting that discovery learning reduced load by elimination of the extraneous working memory load by use of some problem solving strategies during learning. However, while there is clear evidence that schemata can aid what Miller (1956) called 'chunking', there is no evidence that discovery learning will lead to this. Indeed, it is more likely that discovery learning will allow increased cognitive load for the learner often needs assistance in grouping ideas meaningfully. The problem of cognitive load will be discussed later.

2.5 Some Conclusions

In conclusion, many western countries have made significant developments in their school science curricula. Despite the high investments and interest shown by pupils to do science in England and Wales, children in general found learning science difficult (Bliss, 1995). The curriculum developments included introducing innovative teaching and learning approaches in school science which took account of the child's cognitive and affective development (Bliss, 1995).

Various areas of research have focused on the structure of knowledge while others have focused on the learner. Further work has laid emphasis on the difficulties learners experience. With Piaget, the focus was relentlessly on the cognitive development in the learner and was concerned with describing and explaining in a very systematic way the growth and development of intellectual structures and knowledge. His work had no direct concern with predicting behaviour and how to teach children (Wadsworth, 1984).

Ausubel focused on the idea of what the learner already knows. Ausubel emphasised the importance of organising the learning to suit the learners and the aspect of existing knowledge as a prerequisite for meaningful learning to occur. He pointed out that the teacher cannot rely on a single method of teaching to lead the children to meaningful learning or to improve the child's level of thinking. Teachers have to plan lessons to include a variety of methods which introduce learners to different ways of presenting information.

Bruner stressed the importance of discovery and his model of discovery learning is based on the assumption that learning is an active, social process in which learners form new knowledge or concepts based upon their prior knowledge (Bruner, 1966). With a strong bias towards learning of science and mathematics, Bruner contends that a learner selects and modifies information, formulates hypothesis and makes decisions, all the time relying on an existing cognitive structure to do so. He asserts that these cognitive structures are essential for the provision of meaning to experiences. To "*go beyond information given*", Bruner (1973) affirms that the cognitive structures also are responsible for the reorganisation of the selected information within a specific domain.

It could be summarised all together in the below figure:

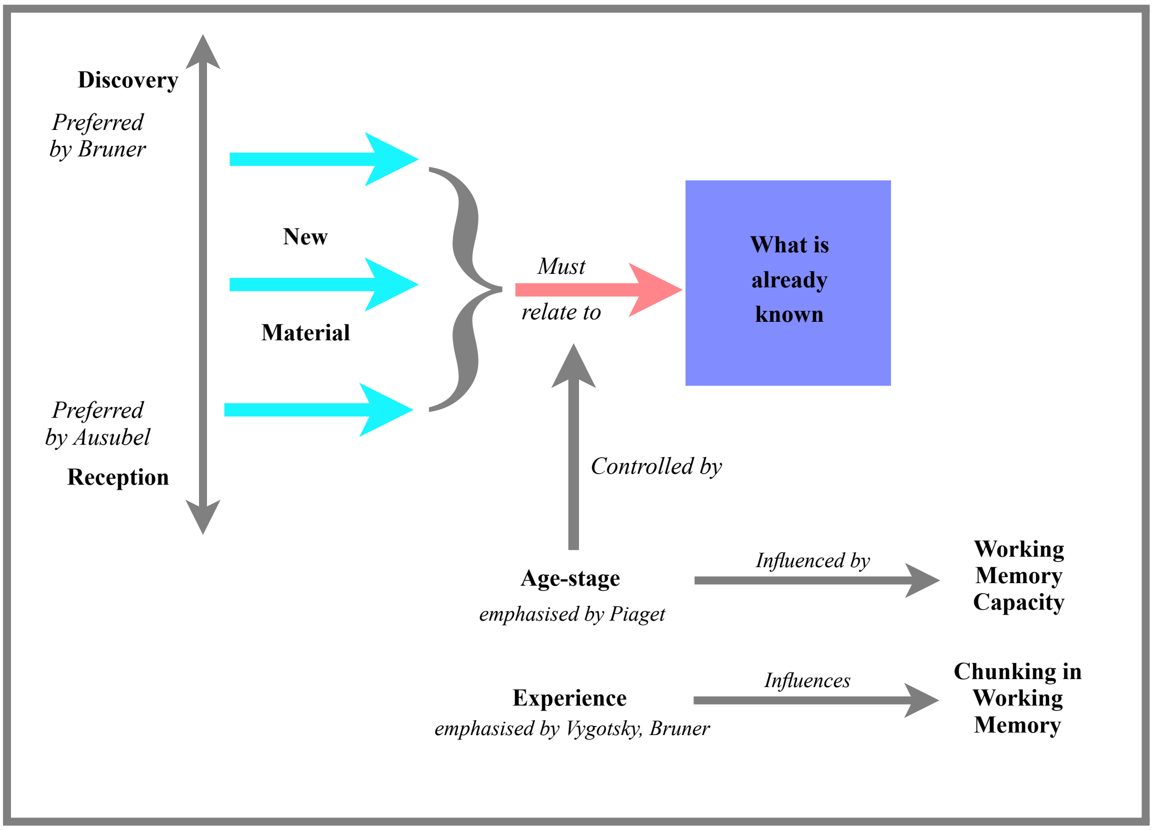


Figure (2.12): *Summary of models of learning*

The next chapter is going to be about the laboratory learning in higher education physics. Also learning in higher education will be considered briefly, and reasons for undertaking laboratory work will be considered along with a review of possible aims for laboratory work, and the various main styles of laboratories.

Chapter 3

Laboratory Learning in Higher Education Physics

3.1 Introduction

It is hard to imagine teaching or learning physics and also other science courses such as chemistry and biology without involving students in laboratory activity. Thinking of schools, Solomon (1980) stated that, "*science teaching must take place in a laboratory .... Science simply belongs there as naturally as cooking belongs in the kitchen and gardening in garden... so the teaching of it must involve real contact with those aspects of nature which are to be studied*" (p.13).

Practical work is often believed to engage students effectively in active learning through practical activities which include laboratory work although the evidence for the effectiveness of learning is not forthcoming. Physics gains its insights through the experimental situations. [Even in theoretical physics, the computer is used to simulate physical situations mathematically and experiment with them. However, in the end of the day, the findings from theoretical physics are tested experimentally.]

However, do the kinds of practical experiences provided at university level assist in the acquisition of desirable scientific skills?

Laboratory learning in higher education will be the focus of this chapter. Learning in higher education will be considered briefly, followed by an historical review about laboratory work. The reason for undertaking laboratory work will be considered along with a review of possible aims of it. Finally, the various main styles of laboratories will be reviewed.

3.2 Learning in Higher Education

Learning in higher education is the learning which should provide society with educated individuals who have developed a range of higher - level transferable skills along with the capacity to apply their knowledge and understanding in one or more specialist disciplines. The transferable skills might include communication, teamworking, self-management skills, leadership, ethical skills, and the use of information technology, along with the more general ability and willingness to "learn to learn", or lifelong learning. Some might include problem-solving skills but there is no evidence that these are, indeed transferable, (Reid & Yang, 2002). There is strong evidence that all these skills are very important in student employment and careers as well as in their life practices (Harvey *et al.*, 1997; Hanson & Overton, 2010).

Redish (1994) asked, as a teacher, why we need a special approach to teach physics. After all, most students learnt in the past without any special approach; what is different today? He suggested some points to answer this question:

- *The goals we want to achieve with these students have changed.*
- *We know much more today about how students learn than we used to.*

- *We have more tools to work with, both technology and a new environment, than in the past.*

Redish (1994) pointed to the importance of enhancing the teaching of physics because increasing numbers of students are now intending to pursue their study at university after finishing school and because there is an increased willingness in scientific fields to take jobs in the technological workplace. Furthermore, Redish pointed out that teachers in the past tended to have little responsibility for the effectiveness of teaching: learning was the responsibility of the learner. Today, the teacher and administrators are often held responsible for the students' learning.

Redish from the University of Maryland Physics Education group, argues that traditional approaches to physics teaching do not work now. In addition, he stated that "*many of our students dislike physics, many feel that it has no relation to their personal lives or to their long-term goals, and many fail to gain the skills that permit them to go on to success in advanced science courses.*" His comments may well be true in many countries but they cannot necessarily be applied to all.

Ramsden (1992) differentiated between two types of learning:

- Learning for real understanding.
- Learning by imitation.

The first one is the learning which adopts a deep approach. Marton and Säljö (1992) explained that students use this approach when they are involved in the task in order to understand that task and in order to acquire meaning. The second approach tends to mean that students acquire information in some kind of random pattern, the purpose being mainly short term recall, usually to pass examinations.

Furthermore, there is another approach for learning which is known as the strategic approach. Entwistle (2000) described this approach as, "*the intention is to achieve the highest possible grades by using organised study methods and good management.*"

Tóth (2007) noted that "*Rote learning makes the finding of the connections between concepts hard and gives separated and non mobilisable knowledge*". He used knowledge space theory to map students' knowledge structures in calculating density, mass-percent, molar mass, and molar volume, working with two different secondary grammar schools in Hungary. One group saw that there is a strong connection between the concept of density, molar mass, molar volume, and the calculation of gas volume while the second group did not have the same idea. Tóth (2007) argued that, "*the reason for this disconnected cognitive structure is the difference in the learning method between the two groups.*" The second group learnt the above investigated concepts by rote-learning using mnemotechnics.

In Australia, Fensham (2004) observed that the physical sciences are facing problems with student disengagement. Fensham discussed some potential reasons for this problem, including a curricular focus on attainment of scientific knowledge without attention to the motivational aspects of science. He focused on the importance of scientific literacy and technology in encouraging an interest in science. However, there is no evidence that his suggested approaches will reduce the problems. The keys are more likely to relate to the extent to which the curriculum taught is perceived by the learners to be related to their interests, priorities and life contexts (see (Reid & Skryabina, 2002).

Research was carried out to consider the interaction of students with an organic chemistry module in a Virtual Learning Environment (VLE) and their interaction with another learning-support Drop in Science Clinic, (DISC). The supported learning was designed to allow the students the opportunity to fit their study at a time suitable to them. The students' performance in the organic section of the examination was compared to that of the physical chemistry section in which the students did not have VLE support material. The results from this study showed that the students did better in their terminal examinations when they interacted with resources on (VLE). In addition, students liked the module support; they described it with positive feedback, and experienced no difficulties in using it. Beside this, the feedback from the students about (DISC) was favourable and useful.

Light *et al.* (2001) summarised some points which are challenges for teaching and learning in higher education:

- *The increasing numbers of students in our classroom.*
- *The increasing diversity of background, experiences, and needs and expectation which our students present.*
- *The emerging curriculum of transferability, which includes acquiring new global competencies.*
- *The insistent pervasiveness of technology, and expectation for its use in academic practice, including electronic learning opportunities for distance learners.*
- *The conceptual shift in our thinking about our practice from teaching to learning, from delivering knowledge to developing and fostering independence of learning in which students develop the ability to discover and reconstruct knowledge (and their lives) for themselves.*

Over the last decades, the number of the students has increased in higher education: for example, in the UK the number of students trebled and the number of universities doubled. Accompanying this enormous rise in the students' numbers has been an increase in the diversity of students, including the growth of the number of women, mature students, ethnic, and minority students, students from less privileged classes and overseas students (DeBard, 2004).

Howe and Strauss (2003) pointed out two other factors. There is an increased focus on consumer demands, with student seen as consumers. There are higher expectations and the perceived educational values have changed. Secondly, today's students are more technologically literate than any generation that has preceded them, with instant communication and access to information available. This has altered the perception of the nature of knowledge and its perceived value.

3.3 Laboratory Work in Higher Education

Having considered learning in higher education very briefly, it is now appropriate to consider learning in laboratories specifically.

3.3.1 Historical Review

More than 160 years ago, the first laboratory work course was formally introduced by Liebig at Giessen (Morrell, 1972) and by Eton at the Rensselaer Polytechnic Institute (Menzie, 1970). During the latter part of eighteenth and early of nineteenth century, practical work was carried out by means of lecture-demonstration. In this way, it was possible to accommodate large number of students with a minimum amount of equipment and material. In order to ensure that these demonstrations could be seen by students, the professors made efforts to make everything large.

In Glasgow, Lord Kelvin (Thomson) became professor of natural philosophy at Glasgow University in 1846, a post he would hold for more than 50 years. During this period, he created the first physics laboratory into a degree course in Britain, keeping this part of the work distinct from the mathematical side. However, his laboratory course was very different from today's laboratory courses for he taught the students the skills and understanding which were related to his own research interests, interests that seemed to encompass every aspect of physics.

Practical physics classes in England were proposed at Oxford in 1860, and started there at University College London in 1866 (Shepherd, 1979) and King's College in 1868 (Phillips, 1981). The first institution to require laboratory work in physics was Massachusetts Institution of Technology in 1869. In addition, the first physics laboratory manual was published in 1873, by E. C. Pickering (Phillips, 1981).

In 1886, Harvard University defined a set of forty experiments in physics; the students have to complete them before entry to the university. The "Harvard forty" would be familiar to almost all tertiary teachers today, this set presenting the classic demonstration of phenomena and principles in physics.

Laboratory classes then gradually developed over the next fifty years until eventually, in 1899, it came to be considered necessary that students be allowed to carry out experiments for themselves. Practical work became an essential requirement for science teaching (Gee & Clack, 1992).

In 1935, Schlensenger studied the contribution chemistry laboratory work was making to general education. He found that students who had previously exhibited "*real interest in chemistry developed the habit of doing their experiments mechanically to get the result expected rather than to observe what is actually going on in their test tube*" (Letton, 1987). Perhaps things have not changed that much!

By the end of the twentieth century, more sophisticated alternatives had been introduced to facilitate effective learning in the laboratories, including pre-laboratory experiences, films video experiment, computer base pre-laboratory, and computer simulations.

Bennett and O'Neale (1998b) proposed guidelines for the design of laboratory courses in chemistry:

- "*Review carefully and take into account the range of unfamiliar ideas and concepts faced by first year students starting laboratory work (many of which may be scarcely relevant to chemical understanding, but which can affect a student's ability to engage with the chemistry);*
- *Design the laboratory course so that a range of skills is introduced in a logical sequence as a coherent package;*
- *Introduce the opportunity for real investigations very early in the course;*
- *Introduce pre and post laboratory sessions which actively engage the students.*"

The above guidelines might apply to physics also. In addition, these guidelines are consistent with the ideas of French philosopher Denis Diderot, who said "*There are three principal means of acquiring knowledge ……observation of nature, reflection, and experimentation. Observation collects facts; reflection combines them; experimentation verifies the result of that combination.*" (Hugh, 1911).

3.3.2 Why Laboratory Physics

For most teachers at school and university levels, undertaking any course in any science without some element of practical work would be unthinkable today. Indeed, laboratory work is considered as necessary and important for any science courses (Boud *et al.*, 1986; Pickering, 1989; Carnduff & Reid, 2003; Deacon & Hajek, 2011). However, the reasons often suggested are inadequate. For physics, it is asserted that, as physics is a practical subject, it needs to be taught using practical work. Another common justification is that there is a need to develop practical skills among students. These reasons are open to considerable criticism (e.g Reid & Shah, 2007).

It is assumed that, because physics gains its insights through experiments, then practical work must be used to teach physics. However, the conclusion does not necessarily follow from the first statement. Learning physics is a very different business when compared to the way research is carried out. Looking at the development of practical skills, the minority of students who will move from their degrees to practice physics in a laboratory sense will need a mastery of very few skills and these are best left to the workplace laboratory. The majority will graduate and never use any laboratory skills in physics.

Nonetheless, there are very sound reasons for including laboratory physics in any university physics course. Thus, years ago, Kerber (1988) pointed to the importance of practical work from the perspective of attitudes while, more recently, Carnduff and Reid (2003) listed some reasons for inclusion of practical work in undergraduate courses in chemistry. Many of these apply equally to physics.

- *Illustrating key concepts.*
- *Seeing things for 'real'.*
- *Introducing equipment.*
- *Training in specific practical skills and safety.*
- *Teaching experimental design.*
- *Developing observational skills.*
- *Developing deduction and interpretation skills.*
- *Developing team working skills.*
- *Showing how theory arises from experimentation.*
- *Reporting, presenting, data analysis and discussion.*
- *Developing time management skills.*
- *Enhancing motivation and building confidence.*
- *Developing problem solving skills.*

Hanif *et al.* (2009) considering higher education physics courses specifically, discuss a list of five general aims originally published by the American Association of Physics Teachers (AAPT, 1997):

1. "The Art of Experimentation: The lab should engage each student in significant experiences with experimental processes.
2. Experimental and Analytical Skills: The lab should help students develop a broad array of basic skills and tools of experimental physics and data analysis.
3. Conceptual Learning: The lab should help students master basic physics concepts.
4. Understanding Basic Knowledge of Physics: The lab should help students understand the role of direct observation in physics.
5. Developing Collaborative Learning Skills: The lab should help students develop collaborative learning."

Deacon and Hajek (2011) list five aims:

1. "*Increase knowledge of physics;*
2. *Develop practical abilities;*
3. *Arouse and maintain interest, attitude satisfaction, and open-mindedness in physics;*
4. *Develop creative thinking and problem-solving ability;*
5. *Promote scientific thinking and provide practice in the experimental methods;*"

In brief, it is possible to summarise some of the ideas in Figure 3.1.

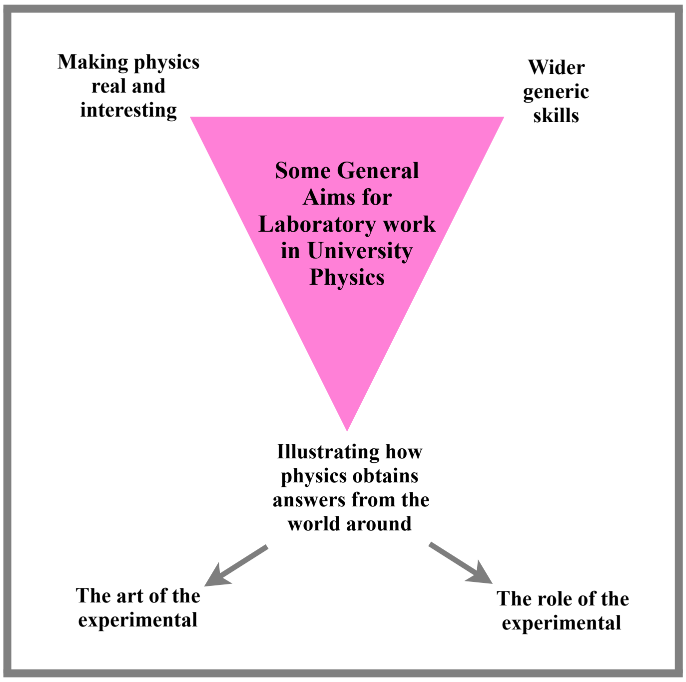


Figure (3.1): *Some Overall aims for Laboratory Work*

3.3.3 The Goals, Aims, and Objectives of Laboratory Work

Laboratory programmes are often very expensive in terms of material and staff time. It is essential that there are clear purposes for the inclusion of laboratory work and that these purposes are communicated clearly to the students. There is a danger for university teachers to be so focused on the physics itself that they lose sight of the needs of the students and how they perceive their learning experiences.

Boud *et al.* (1986) makes this point clearly when they stress that it is very important to state the goals, aims and objectives of any course, in the stage of planning (what to be taught, who is it to be taught, by what means, and most importantly, what are the intended outputs).

Meester and Maskill (1995) found that, in the first year chemistry manuals in the UK, the aims of the course were stated in only half of the manuals. At the same time, the learning objectives were mentioned only in seventeen cases. It is likely that physics would have shown a similar pattern.

When Wills (1974) investigated the student's opinions on the teaching of practical biochemistry as part of a medical course, he found half of the students showed little enthusiasm for laboratory work, and he identified some important points which might be contributing to this problem: he noted the techniques which were used in the laboratory were not always meaningful, the time spend in the laboratory was short and, in addition, theoretical understanding is gained relatively slowly through practical work.

While it is important to specify the aims and goals clearly, there needs to be some agreement on what these aims and goals might be. Some of these studies which investigated these issues are summarised below: Kirschner and Meester (1988) suggested some general objectives for practical work:

- To solve problems.
- To use knowledge and skills in unfamiliar situation.
- To design (simple) experiments to test hypotheses.
- To use laboratory skills in performing (simple) experiment.
- To interpreted experimental data.
- To describe the experiment clearly.

Shymansky and Penick (1979), Black and Ogborn (1979) grouped aims of practical work into four classifications:

- The specific techniques or skills.
- The more abstract skills of experimental inquiry and the scientific method.
- The illustration of idea of subject.
- Aims in the affective domain.

Buckley and Kempa (1971), summed up a list of principal aims to encourage students to gain:

- Manipulative skills.
- Observational skills.
- The ability to interpret experimental data.
- The ability to plan experiments.

While the specific experimental skills in any experiment may not be of great importance for most students, the need to make measurements and gather appropriate data accurately is a broad skill of immense importance. The understandings offered by physics depend on accurate and appropriate data. However, there is a serious difficulty in many laboratory situations. Many years ago, Johnstone and Letton (1990) observed that laboratories, by their very nature, frequently create situations where there is classical information overload. It has been well demonstrated that information overload leads to an almost total loss of any gain in understanding (see Johnstone & El-Banna, 1986, 1989). This issue will be a theme for a later chapter.

Kempa and Ward (1988) noted that observation will depend on two factors: the nature and intensity of a stimulus and also on the observer's perceptual characteristics. For the first factor, observational stimulus must reach a certain level below which, observation will not be made (observation threshold). In this context, Young (1979) differentiated between '*seeing*' and '*observing*', he explained this idea by stating, the learners 'see' many things, but they do not always '*observe*' them. Kempa and Ward (1988) reported that students failed to notice or record one in every three things they saw.

To sum up, Johnstone and Al-Shuaili (2001) stated that "*it is not enough to tell students to observe, they have to be shown how.*" The instructor needs to offer some direction about what is to be observed. The student will need help in order to focus on '*signals*' and leave aside the '*noise*' (Johnstone & Letton, 1990).

At a school level, Hodson (1986) saw that data become observations when registered and interpreted in the light of previous knowledge. For that to happen, it is important to prepare the mind before coming to the laboratory to do the experiments, by using some kind of pre-laboratory experience. In addition, Hodson (1986) remarked "*knowing what to observe, knowing how to observe it, observing it and describing the observation are all theory-dependent and therefore fallible and biased.*"

Johnstone and Al-Shuaili (2001) noted that, "*observation is carried out to check on theories, not only to collect 'facts'.*" Hodson (1986) asserted that, we can reject observation, just as we can reject theories, "*we reject a theory in the light of falsifying observations or we modify those observations in order to retain a well-loved and otherwise useful theory. The view promoted in science courses, that a change in observational evidence always brings about a change in theory, implies a simple direct relationship between observation and theory which seriously underestimates its true complexity.*"

Laboratories offer scope in allowing the learners to solve problems. However, the laboratory needs to give the student the freedom to plan. Sadly, the conventional laboratory is not the right place to allow that. In this kind of laboratory, there are prescribed procedures, the students have to follow them and there is little or no freedom for the student to gain any skill of experimental planning.

In addition to the above, Johnstone and Al-Shuaili (2001) compiled some affective aims mentioned by some researchers concerned about the aims of practical work:

- Interest in the subject.
- Enjoyment of the subject.
- A feeling reality for chemical phenomena.

In brief, the objectives of laboratory work proposed above, can only apply in specific laboratories, in specific disciplines or are so general to be largely unhelpful. It is possible to summarise the aims of laboratory work (Figure 3.2).

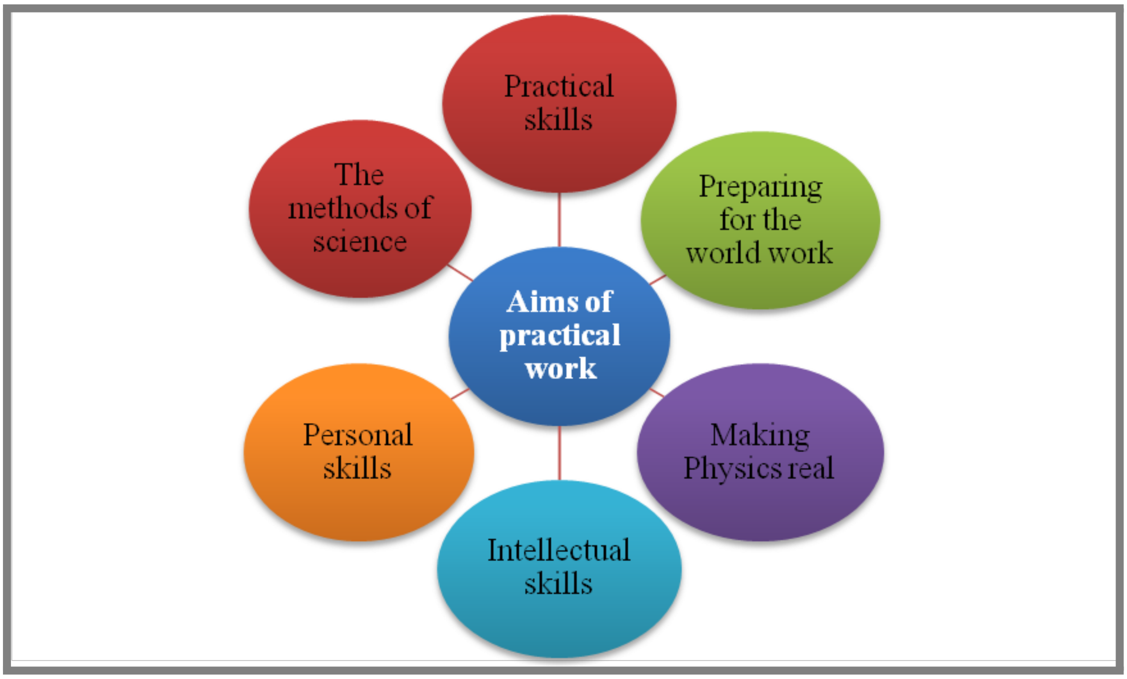


Figure (3.2): *Aims of laboratory work (Carnduff & Reid, 2003, derived from)*

Numerous further attempts have been made to articulate the aims of practical work, (e.g. Kempa & Ward, 1988; Johnstone & Wood, 1977; Kirschner & Meester, 1988; Hackling & Garnett, 1995).

Carnduff and Reid (2003) noted that, "*the pressure of increasing numbers of students coupled with restriction on manpower, material, equipment and contact hours have been significant.*" They listed the pressures related to practical work in undergraduate courses, calling them modern pressures:

- *Cost of materials and equipment.*
- *Safety issues and disposal of chemicals.*
- *Staff and demonstration costs.*
- *Lack of students preparation (due, partly, to outside remunerative work).*
- *School experiences are very different (and entry levels are more variable).*
- *Assessment: what are we rewarding?*

- *Is the credit given worth the effort?*

Tan (1990) argued that demonstration and data-interpretation are a beneficial way forward for practical work. He emphasised that we cannot rely on students using the provided text for this purpose, because he found that the undergraduates integrate poorly their theoretical and practical knowledge and passive learning is common. In addition, he believed that demonstration and data interpretation exercises probably work by forcing them to confront their partial comprehension, rather than follow the steady route of the laboratory recipe. This finding makes an important point. It is often assumed that we learn better by doing things ourselves. However, the actual conduct of the experiments may take up so much mental capacity that nothing is left to think about understanding the meaning of the exercise.

Given the main studies which have identified weaknesses in university laboratory work in physics, it is surprising that things have not changed considerably. Hegarty-Hazel (1990), in the context of the Australian university, pointed out reasons for lack of change in tertiary science laboratory classes:

- Practical work is often administered by graduate students, who have low status, making change difficult.
- More senior staff who have the accountability to change the practical exercises are far away from the educational consequences of the status quo.

Kyle *et al.* (1979) pointed out that the teaching assistants were not usually trained. They recommended that teaching assistants need to be trained well for laboratory work to eliminate this problem. It is an interesting observation that the mandatory training of all graduate laboratory staff in all the sciences was instituted in the late 1990s at the University of Glasgow and this pattern can be seen in many universities today.

Moreira (1980) makes the important point that the students can carry out the experiments quite successfully without understanding what they are doing. This is because they are brought up on a recipe-type approach, with little acknowledgement of the need to apply the concepts. Indeed, the rewards often come in terms of '*correct*' answers and credit is not given for applying the ideas.

In fact, laboratories are very expensive in terms of material, staff, and accommodation. In the light of this, Fielden and Pearson (1978) reported a cost benefit analysis looking at a situation where the traditional laboratory was replaced by a video based approach. Unsurprisingly, they found there is a significant saving of staff time, but we should take into account the time to prepare the video.

If teaching laboratories are to be valuable then it is essential that the time and money spent is justified in terms of the gains for students. With this in mind, various kinds of laboratories are now considered.

3.4 Laboratories Styles

Laboratory organisation can vary considerably. Domin (1999) has described four styles commonly employed in teaching laboratories. These are summarised in Figure 3.3

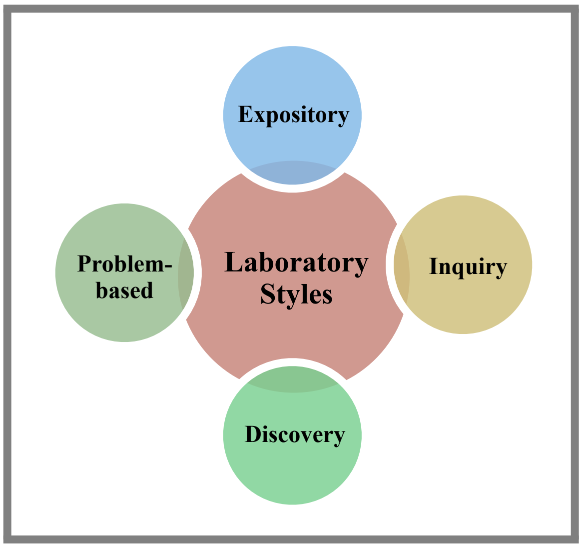


Figure (3.3): *Laboratories Styles (Domin, 1999)*

3.4.1 Expository Laboratory

In this type of laboratory, the students have to follow the teacher instructions or procedures which are usually stated in detail in a manual. The teacher has to define the topic of the experiment and the important feature for this kind of laboratory is that the outcomes are predetermined. Pickering (1989) stated that, "*never are the learners asked to reconcile the result, as it is typically used only for comparison against the expected result, nor confronted with a challenge to what is naively predictable.*"

In addition, Lagowski (1990) described this kind of laboratory: "*within the design of this laboratory (expository), activities could be performed simultaneously by a large number of students, with minimal involvement from the instructor, at a low cost, and within two or three hours time span. It has evolved into its present from the need to minimise resources, particularly time, space, equipment, and personal*". Going even further, Johnstone and Al-Shuaili (2001) see this procedure, although administratively efficient, may defeating the main purposes of laboratory work, leaving the students with few learning gains.

In addition, Johnstone and Al-Shuaili (2001) criticised this type of laboratory for little emphasis on thinking, listing these criticisms:

- *It's "cook book" nature emphasises the following of specific procedures to collect data.*
- *It gives no room for planning after experiment.*
- *It is an ineffective means building concepts.*
- *It is unrealistic in its portrayal of scientific experimentation.*

Johnstone and Wham (1982) see this type of laboratory as a place where there is little meaningful learning, because this type of laboratory has been designed in such a way that the students spend their time measuring and calculating to get a correct result rather than thinking about planning or organising the experiment. Also, this type of laboratory is designed to facilitate the development of lower-order cognitive skills such as rote learning and algorithmic problem solving.

The crucial question here is which aims of laboratory work could be reached by this type of laboratory? Researchers in this field reported that this type of laboratory is unable to provide students with many skills such as designing and planning for experiments. On the other hand, it is possible for students to gain manipulative and gathering skills, but, by little modification of expository laboratories, it could be adapted to achieve far more benefit for the students (Johnstone & Wham, 1982; Meester & Maskill, 1994).

In a school context, Hodson (1996) stated that "*motivation is not guaranteed by simply doing practical work; we need to provide interesting and exciting experiments, and allow learners a measure of self-directed investigation.*" It could be said that the conventional laboratory does not provide interest and enjoyment with practical work. Hodson (1996) observed that the students need an interest in and commitment to the learning tasks. He argued that this comes from personalising the experience by focusing on the conceptual aspects of the experiment, by identifying for oneself a problem which is interesting and worth investigating, also, personalising the experience could be come by designing the procedure to be adopted. This may be ideal but it is hardly realistic, given the organisational constraints.

3.4.2 Inquiry Laboratory (Open-Inquiry)

The inquiry-based approach generates activities which are inductive and the outcomes from this kind of laboratory are not pre-determined. The learner has to formulate the problem, relate the investigation to previous work, state the purpose of investigation, predict the result, and perform the investigation to generate their own procedures. Inquiry laboratory can help the student to construct thinking processes, also provide less direction from the teacher, and the students have more responsibility for determining procedural options than traditional. It gives students ownership of the laboratory activity. And finally, in an activity of this type, the learner will have the ability to engage in authentic investigation processes.

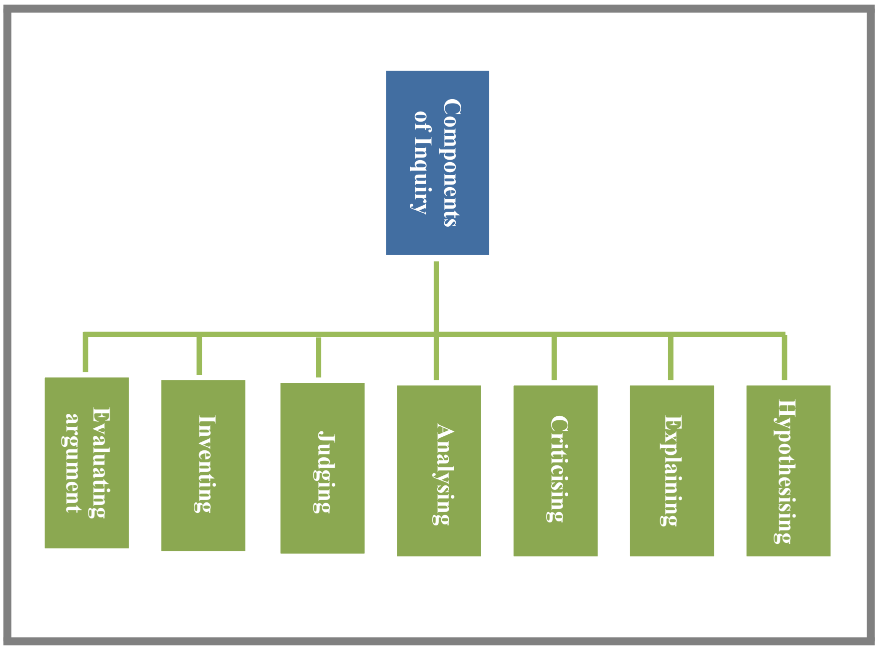


Figure (3.4): *Components of inquiry, (Raths* et al.*, 1986)*

Raths *et al.* (1986) asserted that this type of laboratory helps students to construct thinking processes and has also listed the higher-order thinking processes as components of inquiry: hypothesising, explaining, criticising, analysing, judging.

Johnstone and Al-Shuaili (2001) criticised this type of laboratory under a number of headings:

- Time consuming.
- The cost is very high.
- Emphasis on scientific processes and not enough on science content.
- Very difficult to use this laboratory with large number of students.

Despite this criticism, it is possible to use this type of approach as a short inquiry after the end of expository laboratory in the field of physics and, indeed, Johnstone *et al.* (1994) have described such a use and have shown that it works well in chemistry. Skryabina (2000) developed some interesting post-lab exercises in physics although these were not fully tested in action. However, the warnings of Kirschner *et al.* (2006) are important. It is far too easy to overload working memory with such an open-ended approach. The Johnstone *et al.* (1994) study was careful to address this issue and showed that it could be resolved by means of pre-laboratory exercises. This will be discussed further later.

To sum up, Perry (1999) makes two very important points. Without taking these points into account, there is a risk that the inquiry laboratory will not achieve its goals:

- **Content knowledge:** The student must have a confident grasp of the relevant content knowledge underpinning the experiment. Without this, mental overload is more or less guaranteed and meaningful learning will not take place.

This was a major reason behind the development of pre-laboratory exercises (Johnstone *et al.*, 1994; Johnstone *et al.*, 1998; Johnstone, 1997).

- **Ownership:** in the inquiry laboratory, the learner is given responsibility for planning, design and interpretation. This can give the learner ownership of the work perhaps generating increased motivation and enjoyment. It is interesting to note that the growth of positive attitudes was found to be very marked with this approach to working (Johnstone *et al.*, 1994; Johnstone *et al.*, 1998).

3.4.3 Discovery Laboratory (Laboratory Guided Inquiry)

In this style of laboratory, the learners have to generate their own questions for investigation, with the instructor supporting with minimal guidance. The outcomes from this type of laboratory is predetermined. Also the approach is inductive.

Igelsrud and Leonard (1988) identify four components of guidance inquiry labs:

1. Introduction.
2. Material.
3. Procedure.
4. Discussion.

Igelsrud and Leonard (1988) and Allen *et al.* (1986) suggest that any introductory material should not give any excessive detail about the concepts to be explored in the experiment. Igelsrud and Leonard (1988) recommended that a procedure should be given in a logical order. However, it is important that too much information is not given all at once as this will tend to overload the working memory. Also, the experiment should provide the students with some skills such as identifying variables, controlling variables, and quantifying data.

In addition, Allen *et al.* (1986) provide a template for converting experiments to guided inquiry activities and recommend criteria for selecting experiments. The experiments should:

- "Involve simple and straightforward concepts.
- Collect data using uncomplicated apparatus.
- Provide data suitable for determination of quantitative relationships.
- Test conclusions from the analysis".

Despite this, at a school level, when Bruner (1972) presented his ideas about discovery learning, he did not mean that students have to discover every bit of information by themselves but that they are to discover the inter-relatedness between ideas and concepts by using what they already know. Teachers should teach their students to learn and to learn how to learn. Bruner (1972) thought that a significant difference could be made to a child's intellectual development by careful curriculum design and skillful teaching.

There is no doubt that younger children are naturally curious, a trait that is often repressed by conventional education (Robinson, 2010). However, the idea that learners can discover the inter-relatedness between ideas and concepts by using what they already know is unlikely (Reid & Yang, 2002).

Cognitive theories rest almost completely upon the notion that students have an internal desire to learn by wanting to accommodate and assimilate new information. Snelbecker (1974) said that discovery learning requires that the student participate in making many decisions about what, how, and when something is to be learnt and even play a major role in making such decisions. Instead of being "told" the content by teachers, it is expected that the student will have to explore examples and then "discover" the principles or concepts which are to be learnt.

Many contend that the discovery learning versus expository debate continues a timeless debate as to how much a teacher should help a student and how much the student should help himself (Entwistle, 1981). Discovery learning presupposes a student desire to learn and that it is possible for the teacher to develop learning situations where students can construct their own understandings. On the other hand, it is very difficult in many areas to do that, it is unlikely that students can make discoveries in a few hours which took the best intellects many centuries to develop.

Thinking of discovery learning, Johnstone and Al-Shuaili (2001) stated: "*'Pure' discovery learning, if it ever existed, has come and gone. Guided discovery still has a place, but teachers, driven by external pressures, have little time to indulge in it. Worksheets and blow-by-blow manuals are still alive and healthy, leading to apparently efficient coverage of laboratory activities, while missing much of the point of what undergraduate laboratories have the potential to achieve.*".

Similarly, Hodson (1996) criticised and described discovery instruction as philosophically unsound, and pedagogically unworkable being time consuming and expensive.

3.4.4 Problem-Based Instruction

In problem-based instruction, instead of sitting in the laboratory to follow the laboratory manual, learners are encouraged to solve problems set in real world framework. These problems require real thought and enquiry and this type of learning is almost seen as research based learning, often with the learners working together in small groups. The instructor stimulates students by passing a problem to them, supplying them with necessary reference materials, then, the learners need to prepare the procedure to find the missing information, plan and carry out the experimentation and interpret the outcomes. Here, the guidance is limited and the students in this approach are challenged to "learn to learn." The work in small groups will develop the level of students' understanding. An important point should be said about this style; it is consuming of time, and to make this style more efficient, the learner should have had some experience with experimental techniques. This type of learning is very commonly used in the training of medical students in North American Universities and now gaining acceptance in some British and other European centres (Domin, 1999).

Johnstone and Al-Shuaili (2001) thought that this type of laboratory working is similar to inquiry laboratory work because "*it fosters the development of higher-order cognitive skills through the implementation and evaluation of generated procedures.*"

It is difficult to depend on problem-based instruction as a single method for all learning in the laboratory. However, many laboratory courses seem to follow the set of procedures given below by Johnstone and Al-Shuaili (2001):

- "*Identifying a problem for investigation and putting forward a tentative hypothesis.*
- *Designing an experiment to test a hypothesis.*
- *Performing the experiment and recording the results in appropriate forms.*
- *Interpreting the results and evaluating the conclusions with reference to the hypothesis to be tested.*"

3.5 Conclusion

Meester and Maskill (1994) reported that most university chemistry laboratories experiences are of an expository nature. This is almost certainly true for physics laboratories although there have been good developments in recent years (Sneddon *et al.*, 2009).

It is generally agreed that physics courses in higher education should involve laboratory work. However, there is evidence that not all is well and the students are not gaining as much as might be expected, given the considerable investment in time and resources. Part of the problem lies in the lack of clarity over aims and objectives.

It has tended to be assumed that the actual practical skills are important and that it is intrinsic to physics education to have teaching laboratories because this is how physics research works. There is a lack of recognition of the place of the teaching laboratory as a place where learners can gain experiences of how physics develops its understandings of the world and when the physics taught in lectures can be made more real and tangible.

Carnduff and Reid (2003) considered the role of laboratories in higher education chemistry courses and aimed to offer ways to enhance such learning experiences. They conclude by remarking, '*To change the experience, you don't need to change the experiment, just what you do with it*'. Thus, key issues that need to be addressed are the need for a clarification of the aims for physics laboratory courses in higher education, the need to take into account the limited capacity of working memory and how easy it is to overload this, making understanding elusive.

The latter issue will be addressed further in the next chapter where what is known about the role of working memory in learning will be reviewed. The development of pre-laboratory exercises will be discussed as a way to reduce the mental overload problem.

Chapter 4

Learning and Working Memory

4.1 Introduction

To understand how an individual learns, it is important to know how information is received and processed in the person's mind. Human minds constantly receive information through the five senses: hearing, sight, smell, taste and touch. Some information is remembered for a short period and then forgotten while a little of the large amount of information received may stay in the memory for a very long time. However, it is believed that most information that enters a human mind is almost immediately discarded without even realising it (Slavin, 2000).

The question is why some of us retain some information for a short while or even longer while totally rejecting some other information? Cognitive learning researchers have focused on similar questions like this through the information processing model; the model of learning and memory that describes the process of encoding, storage and retrieval of information in the human mind. Research on human memory has contributed towards understanding of how information is remembered or forgotten (see for examples: Anderson, 1995; Ericsson & Kintsch, 1995). According to Brunning *et al.* (1995), memory is responsible for selecting what information enters the internal workings of the brain, what gets stored and what to retrieve.

4.2 Basic Stages of Information Processing

Contemporary psychological perspectives that study the information processing mechanisms underlying human performance simply assume that the brain is a communication system. Figure 4.1 shows the simple model of a basic communication system as illustrated by (Barber, 1988).

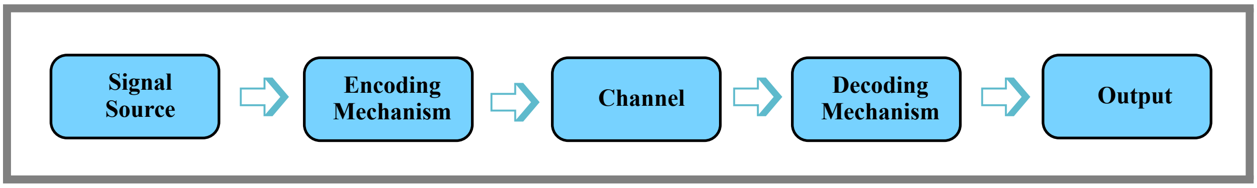


Figure (4.1): *Components of a simple of communications system (Barber, 1988).*

Barber (1988) went on to provide a basic structure which represented the information processing mechanism. Each box in the diagram in Figure 4.2 represents part of the sequence of processing stages at which the input information is transformed in readiness for the next stage.

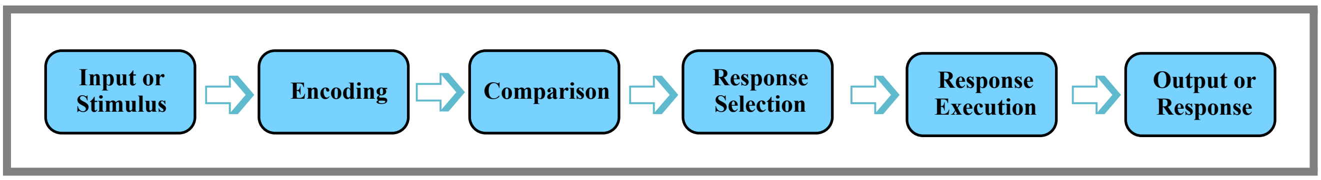


Figure (4.2): *basic stages of information Processing (Barber, 1988).*

The word ENCODING in the structure describes the stage where stimuli are received and internally represented (acceptance or filtering of preferred input signals).

The word COMPARISON relates to comparing or classifying the internal forms of the stimuli with existing possible representation of stimuli.

RESPONSE SELECTION considers the part of the sequence which seeks to match the incoming input signals into a response code.

In RESPONSE EXECUTION the response is organised so that it is directed to the relevant body muscles and by giving instructions on the extent of the response execution.

Looking at the (Barber, 1988) model overall,

- Each stage action-time is independent of the action-time of the subsequent stages, and it does not indicate how the mechanism is able to handle this. However, there are variation on the time taken between receiving the stimuli and producing a response.
- The flow of information within the stage is unidirectional.
- This model concerns the aspects of '*attention*' and '*memory*' which according to Barber (1988), determine what goes in and what comes out respectively.

4.3 Pascual-Leone's Neo-Piagetian Model

Juan Pascual-Leone was a student of Piaget in 1970, and he is one of the researchers who tried to put Piagetian theory on cognitive development into a framework that was compatible with conceptions of the way that our minds handle information. Pascual-Leone proposed that any performance by an individual on a cognitive task involves three major demands on his or her psychology system.

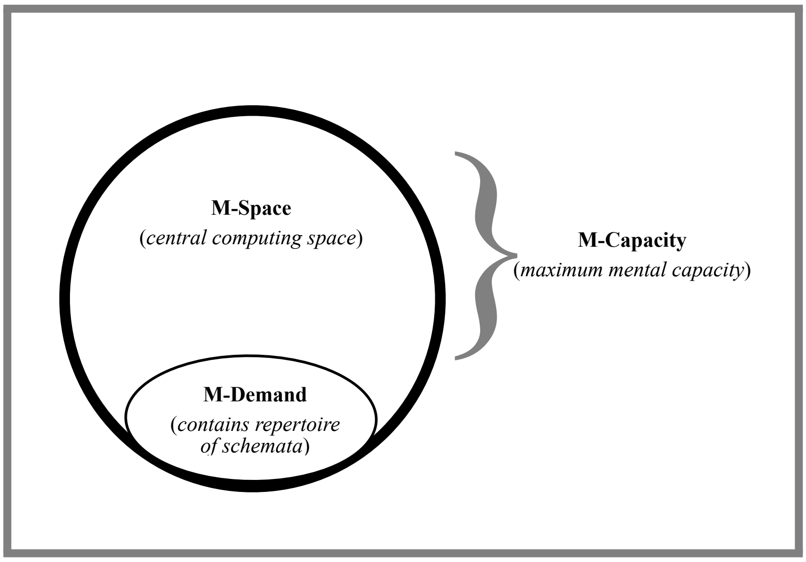


Figure (4.3): *An illustration of the Relationship between Repertoire, the M-Demand and the M-space (Serumola, 2003)*

1. *The repertoire H*

   The mental strategies used to perform the task can be divided into three main categories (Case, 1974a):

   - *Figurative schemata*: the internal representation of items of information that were familiar to the person and had capability of releasing responses from other superordinate schemata.
   - *Operative schemata*: internal representation of orders (rules) that could be applied to a particular set of figurative schemata to produce another set of figurative schemata.
   - *Executive schemata*: internal representation of procedure that were applied in problem solving. It took responsibility in deciding which figurative and operative schema a subject activates in any particular case or situation.

2. *The central Processor M*

   Central computing space (or M-space) is the actual mental capacity of the individual. The computing space (M) repertoire was responsible for the transformation and coordination of information held within the cognitive structure. A distinction was made between the individual's maximum mental capacity or '*structural capacity*' (M_s) and the functional capacity (M_f) which was the amount of M space actually utilised in solving a problem (Case, 1974a). It was suggested that, when a problem was presented to an individual, information had to be processed so that new schemata were obtained. This procedure was carried out by pulling schemata that represented the problem along with existing relevant schemata into one of the channels of the central processor (M).

Pascual-Leone developed a hypothesis that the M-space of an individual is a function of Piaget's stages of cognitive development and therefore grows with age as well as the range of strategies available to the student would grow with experience and with education. Table 4.1 show Pascual-Leone's revision of Piaget's stages with his or her M value.

Table (4.1): *Pascual-Leone's revision of Piaget's stages (Sutherland, 1992)*

Piagetian substage	**Age (years)**	**Value of M-power (a + k)**
Early pre-operational	3-4	a + 1
Late pre-operational	5-6	a + 2
Early concrete	7-8	a + 3
Late formal	9-10	a + 4
Early formal	11-12	a + 5
Middle formal	13-14	a + 6
Late formal	15-16	a + 7

M-power:	the maximum number of schemata available to the individual at any given mental strategy operations.
The letter (a):	denotes the space taken up by the mental strategy (executive schemata) that applied to the task or problem solving.
The letter (k):	denotes the number of units that can be manipulated by the individual simultaneously without causing any confusion.

3. *The M-demand*

This is the demand that the mental strategy places on the mental space. Johnstone (1988) introduced Z-demand which he related to Pascual-Leone's M-demand. Johnstone (1988) described Z-demand in terms of what the student had to consider, recall, and process before starting to tackle the question. He expressed the Z-demand as number of thought steps in a process necessary to solve a problem for the least sophisticated student. Z-demand depends upon the strategy by which the individual finds the solution. Thus, in the same task, a different Z-demand could be experienced by the different solvers for different strategies.

Niaz (1987) has suggested that it is possible to change the M-demand of an item without changing its logical structure. This could avoid overload on student's working memory space. Case (1974b) has pointed out that the learning experiences are assumed to improve a student's performance by providing him with a mental strategy to decrease the task's M-demand.

Pascual-Leone and Case's work formed a basis for several studies on the information processing capacity and mental demand for many psychologists. Many information processing models are described in the literature but with little difference on the function and relationship between the different components of human memory system. Studies of the information processing model propose that a human memory consists of three major components described as sensory memory, short-term memory (now called working memory) and long-term memory (Bourne *et al.*, 1986; Barber, 1988; Brunning *et al.*, 1995; Johnstone, 1993).

4.4 The Modal Model of Information Processing

The information-processing models which have been proposed are largely influenced by the work of Atkinson and Shiffrin in 1968 (see for example Sweller, 1988; Ashcraft, 1994; Brunning *et al.*, 1995). Brunning *et al.* (1995) propose a model, the '*modal model*' (Figure 4.4) that contains common features of all the information-processing models at that time.

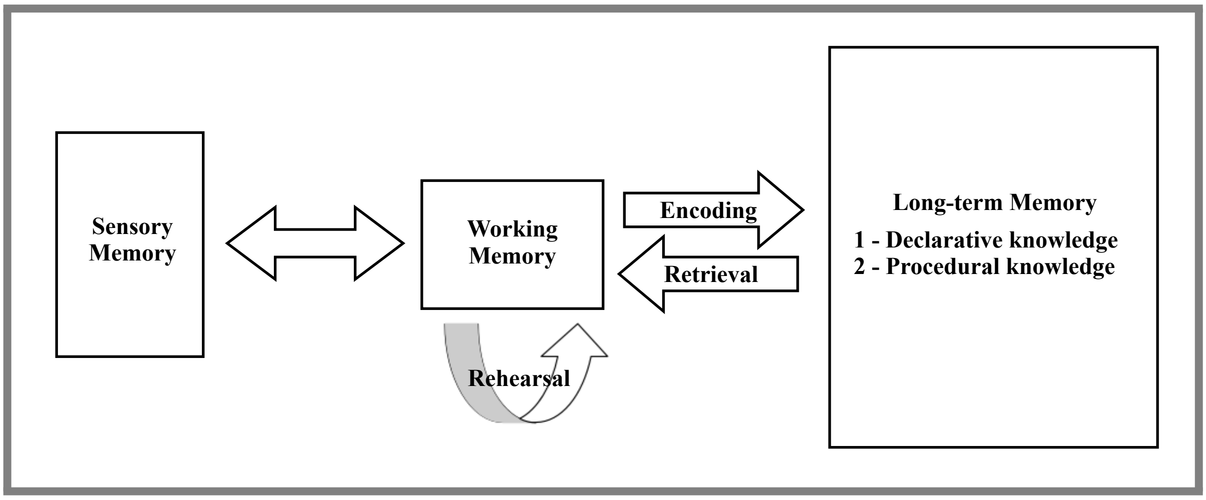


Figure (4.4): *The Modal Model (Brunning* et al.*, 1995).*

This model provides a useful organiser for discussion about memory. Thus, the human memory system consists of three major components: sensory memory, short-term memory and long-term memory. During learning, information is processed through these three components of memory. The information is first perceived by the sensory memory. On being recognised or attended to, the information is transmitted to short-term memory. If linkages are made between the new information and what is stored in long-term memory, then the new information is assimilated and accommodated into long-term memory and stored as cognitive structures or schemas.

Ashcraft (1994) considers the sensory memory has high capacity which allows it to receive all sensory inputs in their original form, and he provided a description of the two types of sensory memory:

1. *Visual sensory*: which receive visual stimuli, and can hold a visual stimuli for approximately one second for it to be encoded and saved into more enduring forms.
2. *Auditory sensory memory*: which receives sound stimuli, holding a sound related stimulus for about four seconds.

The second component of this model is short term memory. Brunning *et al.* (1995) noticed that the significant nature of the short term memory is its delicateness, which is symbolised by a rapid decay of the input whenever a learner's attention is diverted from what is to be remembered. They observed the limitation of the capacity of short term memory to only a few chunks of information. The word '*chunk*' had been previous coined by Miller (1956) to describe what was perceived by the individual as a unit of information.

The third part of modal model is long-term memory: Brunning *et al.* (1995) noted that the information is not the subject of decay as it is in the case of short-term memory, or sensory memory. In addition, the knowledge from long-term memory has been divided into two major distinct types, declarative knowledge which is considered as "factual knowledge", this knowledge enable the individual to recall information such as United Kingdom is in Europe, the week is seven days, Libya is in the north of Africa. Procedural knowledge is said to be dependent, to a large extent, on the amount of declarative knowledge an individual has.

4.5 Johnstone's Information-Processing Model

Johnstone (1993) developed the model further. One of his major insights was that known areas of difficulty in learning in the sciences were related to information overload, the information to be handled *at the same time* in the working memory being likely to exceed the capacity of the working memory. His model drew in ideas from Piaget's stage model, Ausubel's insights on the importance of prior knowledge in meaningful learning, Gagné's learning hierarchy, and Pascual-Leone's idea of limited space related to age (Bahar, 1999).

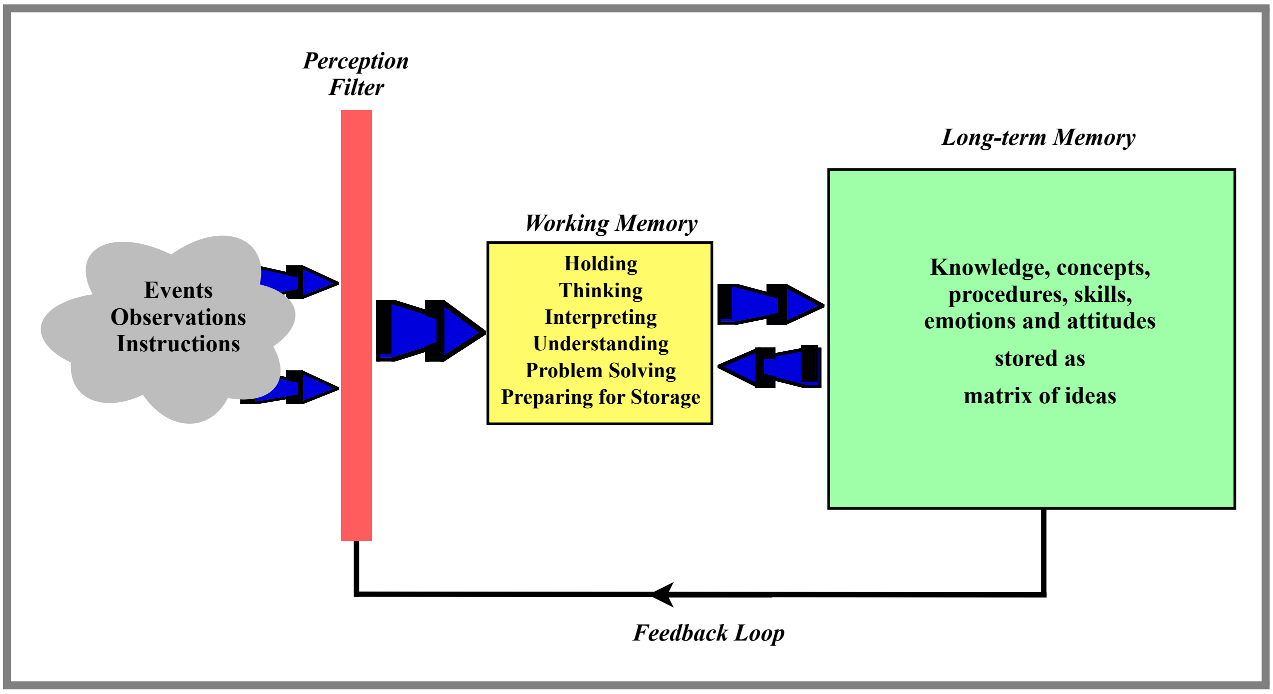


Figure (4.5): *Information Processing by Johnstone Model (Johnstone, 1997)*

From Figure 4.5, the components of the human memory system in the information processing model are Sensory Memory, Working Memory, and Long-Term Memory. This is exactly the same as in the modal model.

4.5.1 Perception Filter

This is also known as sensory memory or sensory register (Atkinson & Shiffrin, 1968). Perception filter was used by Johnstone (1991) in that it describes its function vividly. The amount of information it receives is large and it can hold on to the information for a very short time. The information held is rapidly lost if nothing happens to it.

The perception filter is considered to have a high and unlimited capacity that allows it to receive all sensory inputs in their original forms. The major function of the sensory memory is to select information that is perceived as important by the learner. Johnstone (1993) noticed that the sensory memory acts as a perception filter that selects information. He points out that the perception filter is driven by the long-term memory since the former uses the prior knowledge, beliefs and attitudes stored in the long-term memory to assist in the mechanism of selecting the filtered information. The information is then passed on to the working memory where the subsequent stage of the processing system takes place.

4.5.2 Working Memory

It is the part of memory in which a limited amount of information an individual has at any given moment is held and stored for a short time. It is believed that the short-term memory can hold information without rehearsal for no longer than 30 seconds (Slavin, 2000). Rehearsal by repetition is one way of prolonging the holding of information in the working memory. Once the individual stops thinking about a particular thing, it rapidly disappears from the working memory.

The space used to be known as short-term memory but the known functions of the space have led to the broadening into the idea of working memory space. The name better reflects the notion that it is not only a space for storing information for a certain time but it is a space for processing and transforming information. It permits us to keep information long enough to make sense of sequences of words and directions, to solve problems, and to make decisions. According to Johnstone (1984), working memory is *"that part of the brain where we hold information, work on it, organise it, and shape it, before storing it in the long-term memory for further use."*

Although the short-term memory is usually regarded as synonymous with working memory, Johnstone (1984) provides a distinction between the two by giving the following example. If an individual tries to memorise a sequence of numbers, he may be able to recall it in the same order within seconds and without any processing taking place. Thus, the memory space is used completely as a short-term memory. If he is asked to perform some arithmetical operations on a set of numbers, obviously a working process has to take place and the memory space is now used as a working memory space. As mentioned earlier, the space of the working memory is limited and has the responsibility for holding and operating processes (Baddeley, 1999).

In some brilliant work, Miller (1956) found ways to measure the capacity of what he knew as short-term memory. He found that the average capacity for adults is about seven plus or minus two (7±2) separate *chunks*. *Chunks* are parcels of information, the size of which is in the control of the learners. It might be a single number or a single letter or many pieces of information grouped together. Chunking is the process of grouping information into parcels, which are easy to handle. By the process of *chunking*, working memory space can be used more efficiently because the learner can arrange items in groups of data.

4.5.3 Long-Term Memory

Johnstone *et al.* (1994) described the long-term memory as a large store where facts are kept, concepts are developed and attitudes are held while Ashcraft (1994) described it as, "*the ultimate destination for information that one wants to learn and remember and also the place to store the information on a relatively permanent basis".* Brunning *et al.* (1995) held a similar understanding when they described the long term memory as, "*a permanent repository of information that one accumulates over periods of days, weeks, months and years*". In other words, it could be said that this is the part of the memory where information is kept for long periods of time. After we learn a fact (like the times-table in mathematics) we are likely to know it tomorrow, next month and even for the rest of our life. Unlike sensory and short-term memory, it is unlimited, not easily disrupted, and indefinite. Thus, it seems to be remarkably stable and long lasting and to have a very large capacity.

Johnstone (1997) offers an incisive insight into how information can be stored in long-term memory:

- *"The new knowledge finds a good fit to existing knowledge and is merged to enrich the existing knowledge and understanding (correctly filed)."* By this way of storing, the learning which is going to produce is meaningful learning, also the information is this case is very easy to retrieve and almost never lost.
- *"The new knowledge seems to find a good fit (or at least a reasonable fit) with existing knowledge and is attached and stored, but this may, in fact, be a misfit (a misfiling)".* This way of storage leads to misconceptions, which are very persistent and very difficult to change.
- *"Storage can often have a linear sequence built into it, and that may be the sequence in which things were taught."* By this way of storage the learner memorise information like the alphabet and can be accessed in only one way.

This type of memorisation is useful in some cases although it is often slow and needs a lot of effort.

- *"The last type of memorization is that which occurs when the learner can find no connection on which to attach the new knowledge."* This type leads to what is called rote learning, and the information from this type of learning is more easily lost and more difficult to retrieve."

Tulving (1993) and Squire *et al.* (1993) consider the long-term memory consists of at least three components: episodic, semantic and procedural. Episodic memory is concerned with the recollection of experienced events and episodes that an individual might have such as a conversation one had with the friend yesterday or the death of a parent many years ago.

According to Slavin (2000), semantic or declarative memory contains the facts and the vast network of conceptual information underlying an individual's general knowledge which also includes problem solving skills and learning strategies. Solso (1998) believed that semantic memory is naturally expressed as '*remembering that*' or '*knowing what*'. Meanwhile, procedural memory refers to '*knowing how*' to perform certain activities like how to write, how to drive a car and how to play chess. Maxwell *et al.* (2003) carried out a study, noting that some of the procedural memory such as eating, walking and talking may be activated automatically without the need for high levels of conscious attention.

Moreover, regarding the three components of the long term memory, Slavin (2000) differentiated between them in terms of how information is stored and organised:

- Information in episodic memory is stored in the form of images that are arranged on the basis of when and where events happened, while, information in semantic memory is arranged in the form of networks of ideas. Finally, information in procedural memory is stored as a complex of stimulus-response pairings (Slavin, 2000).

- Information comes from sensory to the long term memory through the working memory, and the information remains in working memory mainly through rehearsal, However, the transfer of material from working memory to long-term memory requires concentration. It is not a simple rehearsal but it requires encoding which means transforming the information and representing it in another way.

Encoding is depending on the experience of the individual; in addition, this information is encoded into:

- The verbal coding system which is linguistically adapted information such as words, stories, discourse, or;
- The imaginably coding system which is adapted for non-verbal information such as pictures, sensations, sound.

Paivo *et al.* (1988) found that, if information was coded into both systems, memory is enhanced in the sense that the information can be recalled more easily, whereas, if information was coded only into one coding system, it was less well recalled.

4.6 Overloading Working Memory Space

Johnstone (1997) has the essential importance of the limited capacity of working memory:

> *'If there is too much to hold, there is not enough space for processing;*
> *if a lot of processing is required, it cannot hold much.'*
>
> *(Johnstone, 1997)*

As it is indicated above, Miller (1956) found that the average capacity is about seven plus or minus two (7 ± 2) separate *chunks*, or in other words, the short term memory has very limited capacity. A learner may be able to handle a learning task perfectly, when it is equal to or less than his measured working memory capacity. Then, what happens when the learning task is beyond the working memory capacity of the learner? Overloading will occur unless the task is rearranged into manageable and effective chunks.

Research has revealed many areas where overloading is common. These include:

- During practical work (Johnstone & Wham, 1982);
- During lectures in higher education (Johnstone, 1999);
- In examinations (Johnstone, 1988);
- When learning in a second language (Selepeng, 1995).

Barber (1988) pointed out that working memory can be easily overloaded when faced with irrelevant information, unfamiliar terms, novel concepts and difficult formulae. Johnstone and Wham (1982) demonstrated that, during laboratories, students' working space memory overloads easily because too many functions are required to be manipulated simultaneously and learning in the laboratory situation may fail. Students have to carry out many tasks at the same time: to think back to the theory, names of apparatus, to know materials; to deal with new written instructions, new skills, and new verbal instructions. By being required to do all these tasks simultaneously they may well reach a *state of unstable overload* (Figure 4.6). Johnstone and Wham proposed that overload in working memory appears when the learner cannot distinguish the *noise* from the *signal*. The term *noise* was used to describe the non-essential and irrelevant information that the teacher and learning context are transmitting to learners while the term *signal* was used to describe the essential and useful information that the student needs for the task in hand. Figure 4.6 shows the picture (Johnstone & Wham, 1982) developed to illustrate the potential overloading of working memory in practical work.

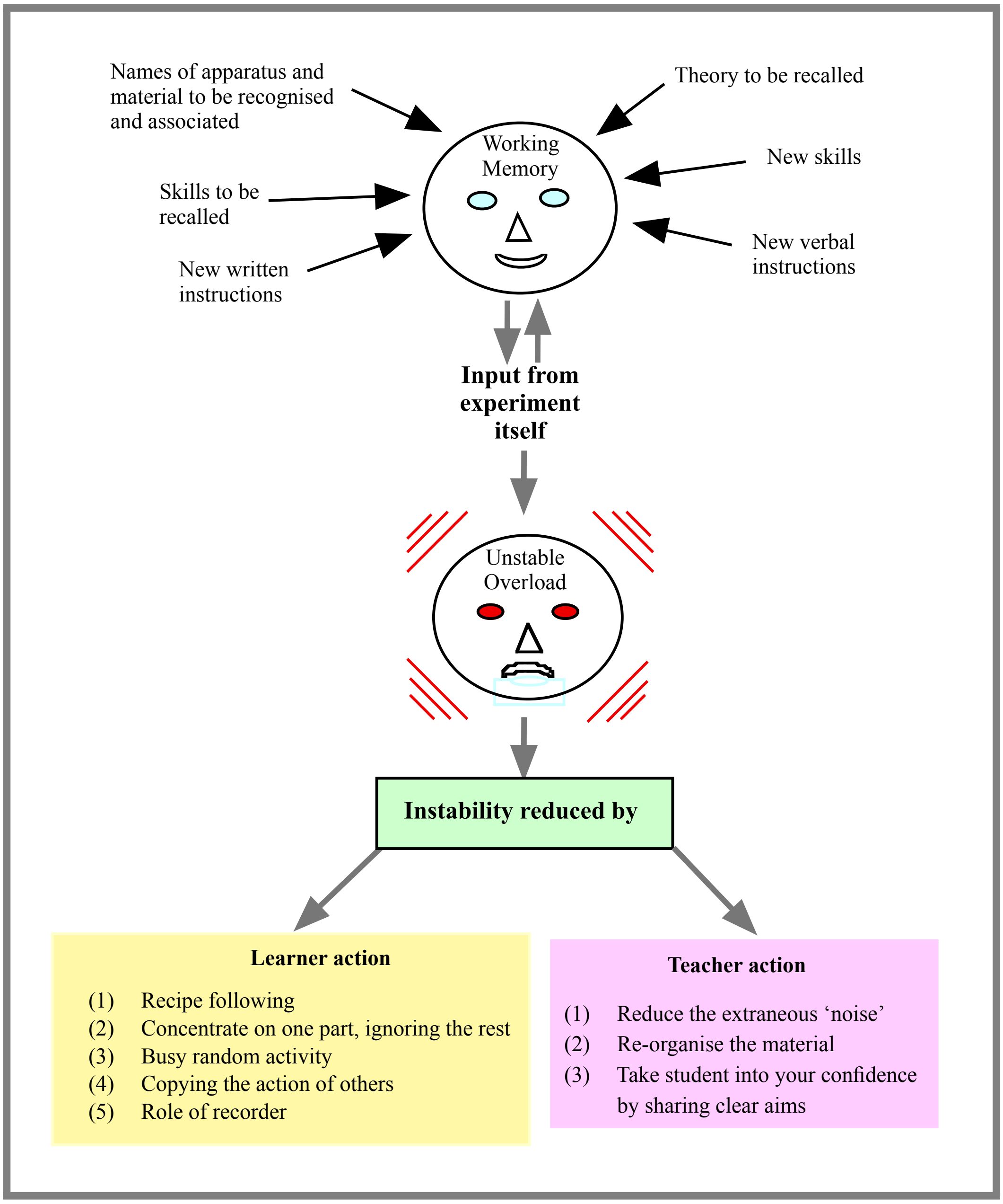


Figure (4.6): *Cognitive Overload in Laboratory Learning (Johnstone & Wham, 1982)*

Johnstone *et al.* (1998) carried out research about overloading of working memory space in university physics laboratories. They predicted that working memory overload would greatly hinder understanding and that student attitudes would deteriorate as a result. They introduced short pre-laboratory exercises with the deliberate aim of reducing this overload. Using a very robust experimental research design, they showed very marked improvement in performance (in terms of understanding) when students had undertaken pre-laboratory exercises. They also found quite dramatic changes in attitudes, with markedly more positive attitudes showing.

This new approach of pre-laboratories was later extended to develop pre-lectures. Johnstone (1997, 1999) pointed out that overloading might not only happen during laboratory learning but also during lectures. Lectures constitute a major way of teaching in higher education. Here, students may try to squeeze everything into their limited working memory space. This includes taking down notes either from the board or from the lecturer's spoken words to try making sense of what they are writing down and then trying to understand them. Overload is almost inevitable. In a series of studies, pre-lectures were developed and tested. These aimed to prepare the mind for learning and thus, reduce potential working memory overload. The outcomes were again quite remarkable, showing very large gains in learning when pre-learning was employed, and are summarised in (Sirhan *et al.*, 1999; Sirhan & Reid, 2000).

Selepeng (1995), who conducted a study about learning in a second language, found that the process of translating one language to another in a learning situation used up about one 'chunk' of the working memory space. This means that learning in a second language is more likely to lead to working memory overload.

Research in the field of science education had suggested that overloading of working memory was very likely to happen during examinations. Johnstone (1988) points out that an overloading may make further demands on an examination candidate by requiring the student to break down a question into sub-goals and chunk information and then into usable units for use in working memory. He also mentions the redundant noise in the working memory such as the superfluous information or context which can drown out the signal. For a candidate with a small working memory capacity, the irrelevant information can only worsen the performance. This was tested by Johnstone and El-Banna (1986, 1989) and it was found that, when a student's working memory was overloaded, performance dropped very markedly: indeed, the average performance dropped from about 75% success to about 25% success when overload occurred.

Bahar *et al.* (1999) has summarised research studies in the field of science and mathematics education in relation to working memory overload:

- *Working memory can be easily overloaded, because of its limited capacity (e.g. with unnecessary information, unfamiliar vocabularies, negative questions),*
- *Overloading the working memory can be an obstacle to acquiring the information,*
- *If working memory is overloaded by too many pieces of information, the processing of this information cannot take place unless such information can be effectively chunked,*
- *There is a relationship between the working memory capacities of students and their performances in problem solving and in exams.*

4.7 Conclusion

The information-processing models are the bases which help teachers and educators in all levels of education to understand diverse factors of individual differentiation in: perceiving information; encoding information; transferring information; scanning the representation of the information; and working memory capacity. Differences in the above factors lead individuals to have different learner characteristics. Differences may also account for variations in ability and achievement.

Educators must pay more attention to the quality of students' learning processes rather than focusing on the transmission of knowledge, and by taking this into account. Students will be guided towards approaching learning deeply and not superficially.

As information processing was steadily researched and its importance understood, the model of Johnstone has captured many of the insights of others:

- Long term memory controls selection of new learning.
- The working memory capacity determines what can be handled.

The model has helped teachers to understand that filtration takes place in the mind of each student, by which the things we are teaching are considered to be important or unimportant, understandable or baffling, interesting or boring. All this is controlled by what is already held in long-term memory. It has also pointed to the limitation of working space in the information processing train. In both of these areas, learning could be not effective.

Finally, it could be said that the overload of students' "Working Memory Space" is the most critical underlying reason for student difficulties (Johnstone & Letton, 1990; Baddeley, 1999; Reid, 2009). Overloading can happen during different places such as: during practical work (Johnstone & Wham, 1982), during lectures in higher education (Johnstone, 1999), also could occur in examinations (Johnstone, 1988), Learning in a language other than one's mother tongue can also contribute towards overloading (Selepeng, 1995), also could occur during solving problem (Niaz, 1987). The next chapter will be about how students view learning.

Chapter 5

How Students View Learning

"A fundamental belief in students is more important than anything else. This fundamental belief is not a sentimental matter: it is a very demanding matter of realistically conceiving the student where he or she is, and at the same time, never losing sight of where he or she can be."

(Perry, 1999)

5.1 Introduction

There is no doubt among educators that learners are the core part of the entire education process. Perry (1999) argues that we need to listen to learners in order not to lose sight of where students are or can be in their developmental process through college. Perry was one of the educationalists who were trying to study the individual human development of university students (Finster, 1989).

During the 1960s and 70s, Perry developed an intellectual and ethical developmental scheme, based on extensive observation. Perry conducted a longitudinal study to develop a scheme for intellectual and ethical growth. He used extensive interviews to explore the variety of ways that students viewed learning. He attributed this to students' different experiences and the variety of ways in which students went on to assimilate that experience. The sample of this study was drawn from Harvard and Radcliffe Universities students. Perry was very sensitive to students' views and he spent a long time interviewing them in order to generate his intellectual and ethical developmental scheme (Perry, 1999).

Perry's scheme developed from students' own accounts of the lives they lived at college, because Perry believed that, in order to develop a faculty, the instructors would have to start off with the development of the students. He believed that understanding students' development started with their voice, their experiences and their meanings.

This chapter will cover different aspects of the Perry scheme. It will outline the original scheme and discuss the adaptations of it. Strategies, which have been suggested to help students to grow intellectually, will be discussed. The students' perceptions of learning as Perry described them will be discussed in light of other contributions from the literature. Finally, the Perry scheme of intellectual development will be discussed critically.

5.2 Perry's Scheme of Ethical and Intellectual Development

First year students made up the sample at the start of his research. They were interviewed and he found that students held a variety of perceptions about learning.

Perry regarded that these reflected student individual differences. The same sample was followed during the ensuing years and he and his colleagues were surprised to find that students' perceptions were developing logically as they progressed. They observed many changes in the way the students were looking at the world around them as they progressed through their degrees. Perry had a strong belief that these positions were not rigid stages, but 'temporary resting' positions (Selepeng, 2000). He argued (Selepeng, 2000) that students should be viewed as being in developmental positions on a developmental continuum at any stage during their educational process.

Perry and his colleagues had used open-ended interviews to develop their initial scheme of intellectual development. Usually they used the *Checklist of Educational Views* (CLEV) as a base to select their sample. They devised this measure in order to identify the students along the dimension they desired (Perry, 1999).

In order to check the validity of Perry findings, four judges were invited to participate and validate the process. Four complete, unedited transcripts of four-year sequences of the interviews with each student were given to them. The judges were asked to rate each of these interviews for each student independently of other judges. After they finished the rating, Perry and his team had a meeting with the judges to discuss their experience. Perry and his colleagues were trying to find if the judges would agree in matching interviews with positions on the chart at a level of agreement not exceeding that attributable to chance (Perry, 1999). The results showed that the interviews were reliable.

Perry (1999) believed in '*developmental instruction*', which stresses the employment of procedures or approaches intended at encouraging cognitive and affective growth in students, and based on the nature of the students themselves. Perry recognised nine different ways by which they viewed their lives. Figure 5.1, below, gives a brief outline of the scheme.

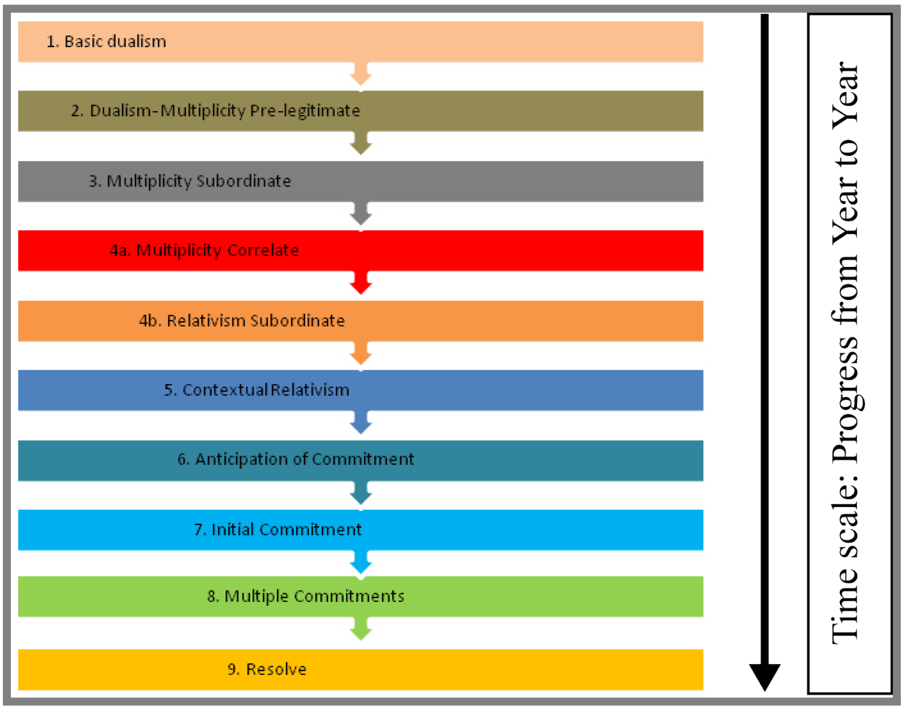


Figure (5.1): *A brief outline of the nine positions in Perry's Scheme of Ethical and Intellectual Development illustrating how the levels overlap*

Perry introduced a concept called "*positions*", which is describing the intellectual level of the learner. He suggested that students could be in different positions at the same time with the respect to different subjects and experiences. He also argued that the developmental process is continuous in all directions. He made this clear when he said '*Perhaps development is all transition and stages are only resting points along the way*' (Perry, 1999).

According to Perry, the positions of the students were not rigid or fixed. For progress through the developmental continuum, there should be challenges and encouragement in line with activities associated with the next higher position.

According to Perry, these positions were arranged into a developmental continuum. He called these positions '*forms*' or '*structures*' of intellectual and ethical development. He observed that the students' views became more complex and sophisticated as they progressed through their study years at college. Thus, position 1 is the most basic and position 9 as the most advanced (Selepeng, 2000), as shown in Figure 5.1.

Perry suggested that the early four positions elaborated to what he called dualism. He stated that students believe, to varying degrees, on an existence of right or wrong, good or bad, black or white knowledge. From the fifth position students start to recognise the contextual nature of knowledge. The last four positions involve the various processes undergone by students as they strive to make commitments in association with different aspects of their lives (Selepeng, 2000).

Perry and his team noticed that college students are usually somewhere between positions 2 and 5 in most aspects of their learning. They also observed that students are usually beyond 'Basic Dualism' by the time they reach college (Selepeng, 2000).

5.2.1 Perry's Positions in More Detail

Position one: "*The students see the world in polar terms of 'we-right-good' vs. 'other-wrong-bad'. Right answers for everything exist in the absolute, known to authority (Perry uses the word authority to describe sources of information such as teachers, textbooks, lecturers and other students) whose role is to mediate (teach) them. Knowledge and goodness are perceived as quantitative accretions of discrete rightnesses to be collected by hard work and obedience (paradigm: a spelling test)".*
Position two: "*The student perceives diversity of opinion, and uncertainty, and accounts for them as unwarranted confusion in poorly qualified authorities or as mere exercises set by authority so we can learn to find the answer for ourselves*" (Perry, 1999).
Finster (1989) brings positions 1 and 2 together and labels this as position A, describing this position as dualism. According to Perry, this position includes the most fundamental ways in which students look at their life in education. As researchers found, students view the world around them in a rather clear-cut manner, everything is looked at from extreme points of view.

Dualism consists of the simplistic right/wrong or black/ white view. Correct answers always exist, and learning them is paramount - the more of this knowledge which is ingested, the better the student (Gray, 1997). The learners in this category view the knowledge as an absolute and any uncertainty is temporary (Finster, 1989). They also believe that each question has an answer and the authority's job is to give the answers.

From the sample which Perry used in his research, no freshman student was found to be in position 1 at the end of first year, but some of them described themselves to be at that position when they arrived at the college (Perry, 1999). Perry noticed that, by the time the students reach university, only a very small percentage would still be in this position, those few who come in at this level '*give it up*' within a few months after experiencing '*the real world*'.

Moreover, Perry pointed out that those students who entering college at this position (an almost 'closed and rigid' way of looking at things) would not remain forever here. He argued that as students interact with others outside the classroom, and as they begin to get exposed to the extra-curricular discussions where they tend to oppose each other's views, there begins to be a change in the way they look at things. This realisation of existence of other ways of looking at things is then transferred to the classroom. This, according to Perry, is when they move on to the later stage of the 'A' position (which could be interpreted at this position as position 2).

Many attempts were made to come up with some new approach to help students to develop intellectually. However, Wood and Sleet (1993) argued that changes are required in context, presentation and expectation rather than in content in order to develop students' positions. They suggested useful guidelines that change or keep student's position. In the context of laboratory work and group work, Wood and Sleet (1993) offered guidelines to keep students at level A, make them feel comfortable and secure by doing the following:

- "*Avoid anything controversial, any exceptions, anything where the teacher says 'it is not known'.*"

- *Do not require students to evaluate source of information critically other than information provided by teacher.*
- *Go over many examples of the same thing.*
- *Examine knowledge only.*
- *Make practical work verify theory, give 'blow by blow' instructions with detailed (mindless?) recipes to follow, mark only the finished article of a practical report.*
- *Do not ask awkward questions during practical work.*
- *Be available at all times to answer questions".*

Alongside this, Wood and Sleet (1993) provided some points about how to challenge level (A) student's perception, and encourage them towards higher positions.

- "*Teach general problem solving strategies as opposed to the method for specific problems.*
- *Give students some responsibility for finding information from a variety of sources and for designing their own practical work.*
- *Direct students to sources of information which may sometimes disagree.*
- *Provide group problems on paper and in the laboratory to foster peer group discussion.*"

In brief, towards the end of this position, students realise that multiplicity in opinion does exist, but still this does not change the fact that the '*right answer*' does exist. The important thing, as Perry states, is that a path toward doubt is opened, along which new perceptions will be readily assimilable.

Position three: "*The student supposes that the precise right answer is not completely adequate to gain full marks in the assessment. Exactly what is required is not clear and the student would like some precise guideline about what is expected."*

Position four: "*This position can be divided into two sub-positions: (a) The student perceives legitimate uncertainty (and therefore diversity of opinion) to be extensive and raises it to the status of an unstructured epistemological realm of its own in which any authority's realm where right-wrong still prevails, or (b) the student discovers qualitative contextual relativistic reasoning as a special case of what they want within the authority's realm*" (Perry, 1999).

Multiplism represents the above two positions (3, and 4). In this main position, diversity and uncertainty are recognised but the student is not sure which idea he should follow from the conflicting ideas he has seen. He needs the authority to supply the guide. Furthermore, diversity and uncertainty are recognised as legitimate to the point where anyone has a right to his or her own opinion and all opinions are equal, even those of an authority (Finster, 1989).

The students at this stage continue to battle with their confusions about uncertainties presented by this multiplicity. They eventually endeavour to find out what it is that a particular Authority really wants.

Position five: "*The student perceives all knowledge and values (including authorities) as contextual and relativistic and subordinates dualistic right-wrong functions to the state of a special case, in context.*" (Perry, 1999).

Relativism: This category covers the 4b-5 positions**.** The students at this stage could recognise that knowledge is contextual and relative (Finster, 1989). Even if the right-wrong may apply, it should be applied only within certain contexts and never to make that decision outside the context (Finster, 1989). Also at this stage, students start to realise that personal commitment is necessary to establish an identity and make sense of all opinions. Unfortunately, in this position students cannot make that commitment. Even if students start to realise that knowledge depends on context, they have not attempted to structure their knowledge.

Position six: "*The student apprehends the necessity of orienting himself in a relativistic world through some form of personal commitment (as distinct from unquestioned or unconsidered commitment to simple belief in certainty).*"

Position seven: "*The student makes an initial commitment in some area.*"

Position eight: "*The student experiences the implications of commitment, and explores the subjective and stylistic issues of responsibility.*"

Position nine: "*The student experiences the affirmation of identity among multiple responsibilities and realizes commitment as an ongoing unfolding activity through which he expresses his life style.*" (Perry, 1999).

***Commitment in Relativism**:* this category covers the 6-9 positions. Commitment involves the individual making a choice or decision in the full awareness of relativism. In this category, the student orders his knowledge, recognising that decisions can be made only on a basis of uncertainty. They are prepared to take risks to do so.

5.3 The Relationship Between A Degree of Confidence and Perry's Positions

> *"In terms of confidence, Student A is confident in the system: the teacher, the lecture, the exam. Student C is confident in himself and in his ability to learn on his own or in a group or by whatever method he finds congenial. Student B, however, sits in a trough of uncertainty and low self-esteem."*
>
> *(Johnstone* et al.*, 1998).*

Wood and Sleet (1993) went on to express this in a graph (Figure 5.2).

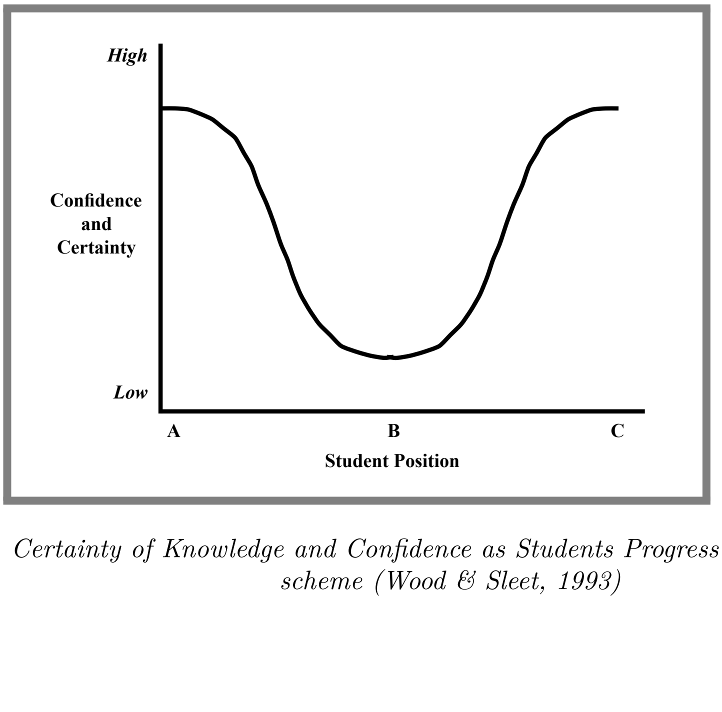


Figure (5.2): *Certainty of Knowledge and Confidence as Students Progress Though Perry scheme (Wood & Sleet, 1993)*

From the above chart, it can be seen that students A and C have high confidence unlike student B who has low confidence. Wood and Sleet (1993) suggest reasons for this pattern which are summarised below.

Student A relies on the authority whereas student C relies on himself. For example, student A considers the lecturer as the only source of knowledge, and then his full trust is given to what the lecturer says. Student C, using many sources of knowledge, comes up with his own ideas about an issue. On the other hand, Student B tends to lose his confidence in both authority and himself. For him, knowledge is not black or white, wrong or right any more but he does not know how to deal with this situation. His role is more than a passive acceptor but he cannot work out his new role. He believes that there should be another source of knowledge other than the lecturer, but this still leaves him with much doubt about the other sources and he still wants the lecturer to confirm the other sources for him. All this leaves student B with more doubts and uncertainty about his learning and makes him less confident (Wood & Sleet, 1993).

5.4 Adaptation Of Perry's Scheme

Perry has developed a very useful scheme which seems to reflect students' perceptions of learning in higher education. However, the nine positions of his scheme are too complicated in practice. For this reason, many researchers, like Finster (1989), Johnstone *et al.* (1998) have tried to simplify it.

5.4.1 Finster's Adaptation of Perry's Scheme

Original Perry's scheme had nine positions and according to Finster (1989), these nine positions can be categorised into four main positions as shown in Table 5.1

Table (5.1): *Illustration of the categorisations of the Perry Positions*

Category	**Dualism**	**Multiplicity**	**Relativism**	**Commitment in Relativism**
Position	1 & 2	3 & 4a	4b & 5	6, 7, 8, & 9

Finster (1991) found that college students are usually at positions 2-5 and those in the first year usually in the 2-3 range. In addition, Finster also found instructors to be between position 6 and 9. Instructors during their discussion of their teaching strategies and their views of education could be categorised according to their discussion:

- Dualist: 10%.
- Multiplist: 30%.
- Relativist: 45%.
- Committed to relativism: 15%.

However, in the classrooms, they functioned at advanced Perry levels. This may lead to suggest that in some cases they might be a gap between instructors' perceptions about the Perry scheme and their real teaching in the classrooms.

5.4.2 Johnstone's Adaptation of Perry's Scheme

An adaptation of the Perry's scheme was made in the late 1980s by Johnstone. This adaptation of the scheme is shown in Table 5.2. He reorganised Perry's scheme into three main positions. This made the scheme more applicable without changing the core issues of the Perry scheme.

Table (5.2): *Johnstone Adaptation of Perry Model (Johnstone* et al.*, 1998)*

Category	**Dualism**	**Multiplicity**	**Relativism**	**Commitment in Relativism**
Position A	1 & 2			
Position B		3 & 4a		
Position C			4b & 5	6, 7, 8, & 9

From Table 5.2 position A represents positions 1 and 2, where dualism is still strong. In position B, the student starts to realise the problems that surround dualism but still has problems dealing with multiplicity. Indeed, it is the most uncomfortable position for students. Position C is the highest position, (including all positions from 4b onward till position 9 in the original Perry scheme). Though Perry said that most students in the final college year are between positions four and five, it is possible for some of them to be in higher positions. Since it is very rare to have students between positions 6 to 9, Johnstone put them with positions 4b and 5 in one position, which is his 'C' position.

Johnstone *et al.* (1998) amplified his model (Table 5.3).

Table (5.3): *Simplification of Perry's Scheme Model by (Johnstone* et al.*, 1998)*

	Student A	**Student B**	**Student C**
Student Role	Passive acceptor	Realises that some responsibility rests with the student. But what? And how?	Sees student as source of knowledge or is confident of finding it. Debater making own decisions.
Teacher Role	Authority giving facts and know-how	Authority where there are controversies, wants guidance as to which answer lecturer favours.	Authority among authorities. Values views of peers. Teacher as facilitator.
View of Knowledge	Factual; black and white. Clear objectives, non-controversial exceptions unwelcome	Admits 'black-and-white' approach not always appropriate. Feels insecure in the uncertainties this creates.	Wants to explore context; seeks interconnections, enjoys creativity scholarly work.
View of Exams	Regurgitation of 'facts'. Exams are objective. Hard work rewarded	Quantity is more important than quality. Wants to demonstrate maximum knowledge quality.	Quality is more important than quantity. Wants room to express own ideas, views.

5.4.2.1 Position A

The students in this position viewed the world around them in a clear-cut manner. All issues are right or wrong, good or bad, true or false. Perry (1999), Selepeng (2000) argued that qualitative meaning has no place in this position. Authority or instructor has the only right to give the right answer for all questions and all other opinions and views cannot be considered and cannot be right. Furthermore, the authority has the only power to assess the opinions and select the correct one for students. The discussion will be according to the order of the above table:

The role of the Lecturers: Lecturers are viewed as authority, and the authority is always right. Because of this, they can be distinguished from students. What the lecturer says must be accepted by students without questioning. Perry (1999) found that most students were not in this position when they finished school and reached university level: only a small percentage of them are still in position A, when they reach university level. Of course, today, most young people know their rights and are not subservient to authority, even those who are still in this position will give up as soon as they realise that life in university is not that straightforward.

The role of the Students: If the lecturer is the authority, then the students have to obey the lecturer without presenting any questions. Students also have a responsibility to learn and memorise everything which was provided by the lecturer, which is considered to always reflect the truth. Furthermore, students have no right to play a role in finding the deeper meaning of things given by lecturers. They do not try to expand their knowledge by themselves because they think this is not their task to do so (Perry, 1999; Selepeng, 2000).

Students will tend to think that, if they oppose their lecturer in their viewpoint, then they should immediately be dismissing their view in favour of a lecturer's standpoint. In this, they think it is not necessary to have any role relating to challenging the accuracy of knowledge (Perry, 1999; Selepeng, 2000).

View of knowledge: The knowledge, which is usually presented by authority, represents the absolute truth. According to Perry, in teaching, the instructors or lecturers are mediating between this absolute truth and the student. "*Judgments can then be made between those who know their stuff and can mediate well and those who don't know, mediate badly and are more likely to be 'impostors'*" (Perry, 1999; Selepeng, 2000).

Perry found that these students seemed to give their lecturers the liberty to enjoy exploring these other '*wrong interpretations*', as long as they are not brought into play where instruction is concerned (Perry, 1999; Selepeng, 2000). All that is expected is for the instructors to '*stick to the facts*' and do '*less theorising*', as some of Perry's students put it (Perry, 1999; Selepeng, 2000).

It has been observed that, even if students can distinguish between good and bad authority, that does not mean they can accommodate this in the nature of knowledge itself (Perry, 1999; Selepeng, 2000). In general they always expect one right answer for each question.

View of exams: Students at this position suppose the assessment procedures are free of ambiguities. This is related to their view that each question has one right answer, and the good student should know all the right answers. Besides this, they view questions which demand students' opinions and interpretations as too much of an unnecessary challenge. However, students do not like to give their own opinions in assessment for two main reasons (Perry, 1999; Selepeng, 2000). Firstly, they think that there is only one right answer for each question. Secondly, they think that they are unable to give their views or interpretations.

According to Perry, when the students enter college at this position, with this rigid and closed view of assessment, they will have difficulty in surviving the degree course. However, Perry found that, later and after these students had interacted with their colleagues outside the classroom and were exposed to extra-curricular discussions where they tend to oppose each other's views, they started to change their view of assessment. This will then be transferred to the classroom. However, toward the end of this position students do realise that multiplicity in opinion does exist but this still does not change the fact that the '*right answer*' exists (Perry, 1999; Selepeng, 2000).

This position denotes the beginning of the movement from the strictly dualistic Position A, and the students are now able to perceive Multiplicity when introduced by the instructor, but does not mean they are ready to accept it as legitimate. All the above perceptions about the roles of lecturers, and the students themselves, and the views of knowledge and exams, still hold, and true knowledge is still seen to exist and dominate everything else, which is still wrong.

5.4.2.2 Position B

The role of lecturers and students: Students at this position start to view the lecturers as the people who are responsible for teaching them the correct ways of finding the right answer. Students are beginning to realise that they have responsibilities toward learning but they still want the instructors or lecturer to show them how. This is because they do not know what to do. In addition, students start to believe that their role as students is more than a passive acceptor of what has been given by the lecturer. However, they do not know what is needed or what should be done by them. They want directions from the lecturer; because they see the instructor is responsible for teaching them these ways (Perry, 1999; Selepeng, 2000).

View of knowledge: In this position, students start to accept that in some situations the truth or the right answer is out of reach. This may lead them to accept that uncertainties are legitimate. However, they still believe that there is only one right answer, and they do not change this belief, the only right answer is not available in this situation because the proper ways of finding it is not available yet (Perry, 1999; Selepeng, 2000). Students also start to accept that the lecturer does not always possess all the right answers, but they become puzzled as to how the lecturer will evaluate the student's answers if he does not know the right answers yet himself (Perry, 1999; Selepeng, 2000).

View of Assessment The students in this position become confused about what is expected from them and they hope to be able to present one argument, which will make the lecturer like their line of thought. They hope this will lead to examination success. They will work hard, and will try their best to make their answer suit the lecturer's way of thinking but this will make them still feel they never know when and why they are going to be either marked down or up. They expect to be fairly treated, or in other words, they believe in rewards for quantity of hard work and not quality of work. For them, the amount of work done by students should be taken into account. They think that Multiplicity will involve an increase in workload. They are expecting to take in everything and they are not expecting to be asked to make their own judgement, which may make them complain about the amount of work needed for exams, they expect to be fairly treated (Perry, 1999; Selepeng, 2000).

5.4.2.3 Position C

According to Johnstone's adaptation of the Perry scheme, this position is considered the highest position. The importance of this level is because universities wish to develop students to levels where they can be functional in the community after graduation.

The students at this stage consider the lecturer as a facilitator of learning rather than being there only to offer knowledge. They also consider him to be an authority, but among other forms of authority like books, papers.

Furthermore, the student accepts responsibility for his own learning. The student feels confident to seek expert help from various sources. The students are not passive learners.

The student in this position believes that the knowledge is constructed in the mind from a variety of sources not just one source, such as lecturer and more than one answer can be legitimate. In addition, the student understands the difference between facts and opinions (Perry, 1999; Selepeng, 2000).

Students view examinations as opportunities to demonstrate their skills in relating between contexts, to seek interconnections, to expand and modify concepts, to weigh up alternative approaches and to aim for scholarly work in which comparison and contrast are considered. Moreover, the quality is seen to be more important than quantity.

5.5 Criticism of Perry Scheme

The Perry scheme originally was very complex but it reflected what Perry found from his interviews, but later many attempts were made to simplify it. Finster (1989) tried to group the original positions into four categories which seem to possess similarities. Johnstone *et al.* (1998) put the scheme in a more easily applicable way without altering the core ideas of the Perry scheme. Thus, the Perry scheme was reorganised as three main positions: A, B and C. Indeed, Johnstone developed ways to assess student positions using self-reporting techniques, thus reducing the need for time-demanding interviews (Downie & Katung, 1999).

In addition, Perry's scheme was criticised with regard to sample; the sample size and type raise many questions about the validity of generalisation. The Perry study was originally conducted with just 84 students and this number seems to be too small for safe generalisation. In addition, these students were in one college, which raises questions about the students in other universities, colleges and specialisations. Socio-economic class, age, and background were always also under scrutiny due to limits in the original sample.

Furthermore, another criticism was addressed to the Perry scheme that was about the ways of choosing the samples. The first sample was chosen using the "*Checklist of Educational Views*" and the second sample was chosen randomly but the main issue here is that both samples were chosen only from volunteers. A question of the other students' perceptions (non-volunteers) is valid here.

Gay (1981) and Cohen and Manion (1997) criticised the longitudinal interview method which was used by Perry to assess students' intellectual development. They considered it to be time consuming and not applicable to large numbers of students. Furthermore, one of the weaknesses of interview is that the interviewee might hide some information during the face to face situation. Later, two methods were developed to assess the students' intellectual development, one of them is called (MID) Measure of Intellectual Development (Perry, 1999) and the other is (LEP) The Learning Environments Preference which was designed by Moore (Perry, 1999). The results from LEP help show student's position and transition. However, most researchers use a combination of MID LEP and Perry interviews.

The Perry scheme can be criticised in relation to cultural perspectives and values, which will affect students' views of learning. Since the original scheme was designed based on the western culture and values in the 50s and 60s, a big question may rise about the applicability of the scheme today with different cultural settings.

Nonetheless, the general findings of Perry have been supported in a number of studies using a survey approach (Downie & Katung, 1999; Mackenzie *et al.*, 2003; Selepeng, 2000; Al-Shibli, 2003). One of the interesting features of these studies is that the development is not neatly linear. It appears that there is a recession in the development towards the end of the four year degree. It is possible that the backwash effect of final assessment may be influencing student views. In an interesting recent study, El-Sawaf (2007) tracked the student perceptions during a degree, compared these to those who had completed a degree and were undertaking diploma studies and to those who were well-established in a teaching career. Undergraduate students' beliefs changed, and that confirmed Perry's assumption that structural change can take place at this stage of life, she found also, beliefs affect teachers' teaching approaches and practises. One issue which arises in the literature on attitude is that different writers use different terms interchangeably, without clarifying the distinctions between them. These terms include '*attitudes*', '*beliefs*', ' *opinions*' and '*perceptions*'. Oraif (2007) tried to resolve the confusion by developing an attitude hierarchy and this is discussed in Reid (2011). Figure 5.3 illustrates the idea.

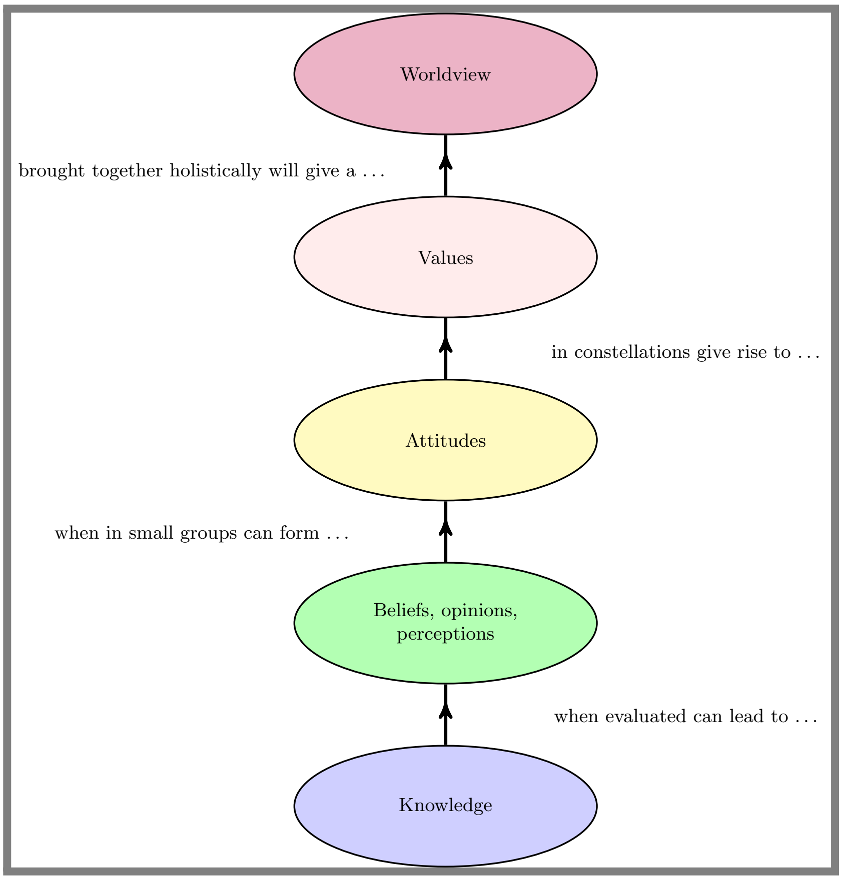


Figure (5.3): *Analysis of words associated with attitude*

The key feature is that an attitude involves a small group of beliefs or opinions or perceptions. A questionnaire measures these and then seeks to deduce what the underlying attitude is. For example, the school student may have developed all kinds of beliefs (through knowledge and experience) relating to, say, physics: laboratories are boring, badly organised, and irrelevant; the teacher is knowledgeable but does not understand me well; the lecturer does not explain well; the instruction sheets are unclear; report writing is pointless; and so on. All these generate a negative attitude towards physics laboratories. Attitudes are highly multi-dimensional and involves a set of beliefs, opinions or perceptions. Thus, an attitude cannot be reduced to a number or to a score.

The next chapter will be about the methodology which has been used in this study for the first, second, and third experiments.

Chapter 6

Exploring Laboratory Learning in Physics

6.1 Introduction

This study is seeking to explore the physics laboratory experience with students at University level and to consider student perceptions of university physics laboratories in Libya. At the same time, the views of university teachers related to university physics laboratories in Libya were also explored. The aim, overall, is to establish ways by which the student experience might be enhanced and to examine the benefits in terms of making the laboratory experience more effective for understanding physics for students in Libya. To this end, measures were made of some learning gains under various conditions.

After reviewing the situation of physics laboratory work at universities in Libya, Scotland and Pakistan and by studying the literature and measurement instruments available, it was decided to start by looking at the first semester students in the faculty of science at Sebha University. The aim was to see how they perceived their school experiences in practical physics, looking back at the outset of their university studies, and also to see how they saw their university experience in practical physics towards the end of their first semester. The plan was to establish a picture of what was going on and where the problems lay.

In Libya, students in the first semester in the science faculty have not yet chosen the specific discipline for their degree but they have to study physics in the first semester as part of one of two groups:

Group A: Zoology, Botany, Chemistry, or Geology in the second semester

Group B: Mathematics, Physics, Computer Science, or Statistics in the second semester

Group B was selected for this study.

The purpose of the survey was to provide an overview of student self-perception in relation to laboratory work in two different places of learning: in the school laboratory, and in the university laboratory.

After reviewing the results from first stage, it was decided to develop a new approach for second stage to make the laboratory experience more effective for understanding physics by testing out some new approaches with students in Libya. For that purpose, the decision was made to apply pre-laboratory exercises before doing the actual experiments and to use post-laboratory exercises after completing the experiments.

In stage three, the pre-lab and post-lab exercises were also employed but the post-lab exercises were extended considerably. The laboratory instructions sheets were re-written completely to make the whole learning experience a more cohesive whole. In both stages two and three, performance in the post-lab exercises offered insight into how well the students understood what they had done. In addition, at the end of stage three, semi-structured interviews were carried out with university teachers to explore the views of university teachers regarding to physics laboratories in Libya.

The overall structure of the stages of the research can be summarised:

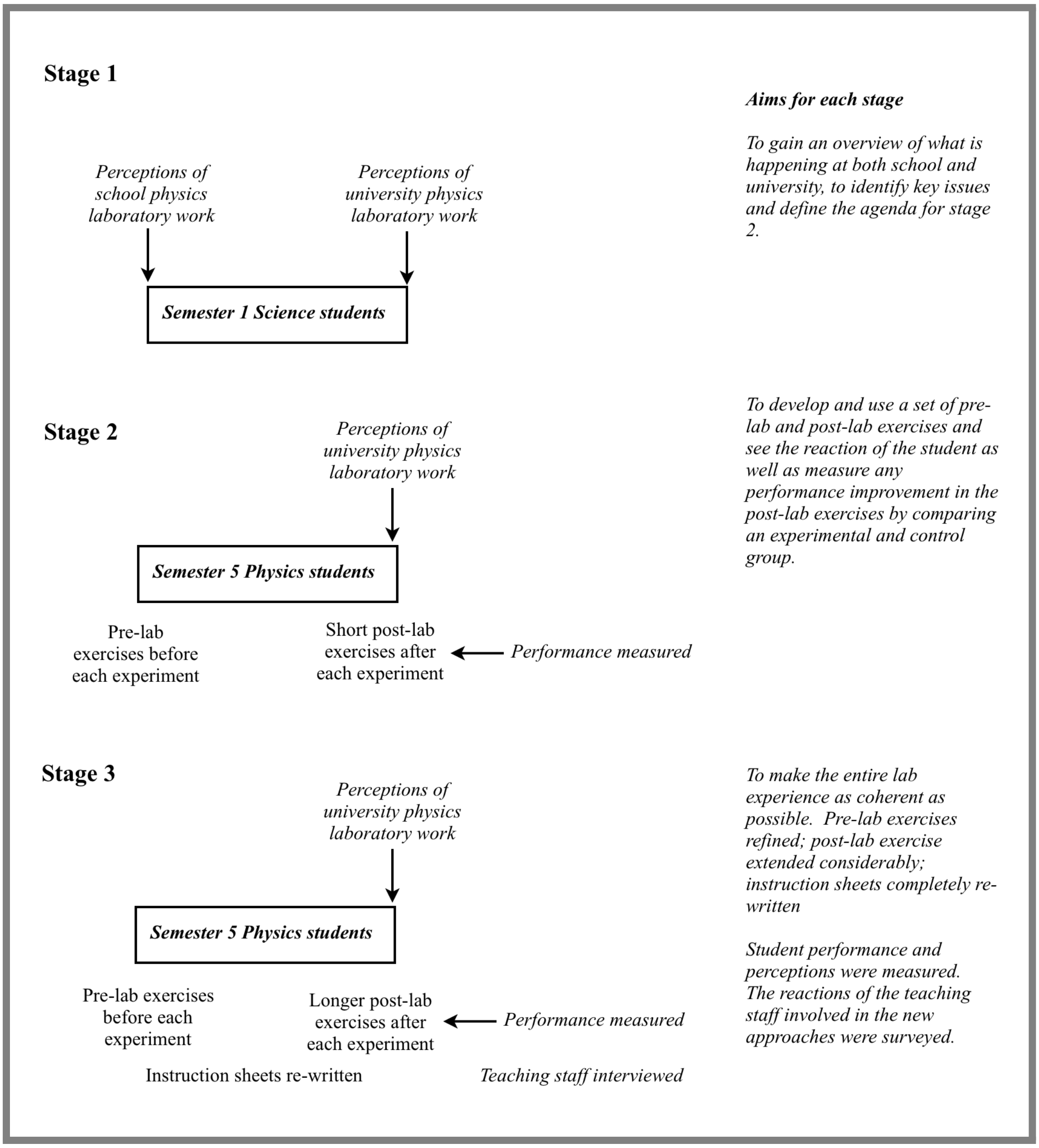


Figure (6.1): *Summary of structure of the stages*

This chapter outlines the methods and techniques which were employed to gather and analyse the data. The data obtained are then discussed in later chapters.

6.2 First Stage

It was decided to use questionnaires to collect data for the first stage to provide an overview of students' self-perception of practical work. Many authors have argued that the questionnaire is a powerful way to obtain data (Best, 1981; Gay & Airasian, 2000; Fraenkel & Wallen, 2000).

Using questionnaires, large amounts of data can be gathered very rapidly, making the approach very efficient. Of course, a questionnaire can offer useful pictures of how respondents perceive things. They do not offer any absolute measurement of anything. However, careful construction and administration of the questionnaire is essential to get the full benefit of these advantages. This was the major priority for the researcher before conducting the survey. In the following section, the construction of the questionnaires will be discussed.

Reid (2006) has offered general guidance on questionnaire construction and this was followed here (Figure 6.2).

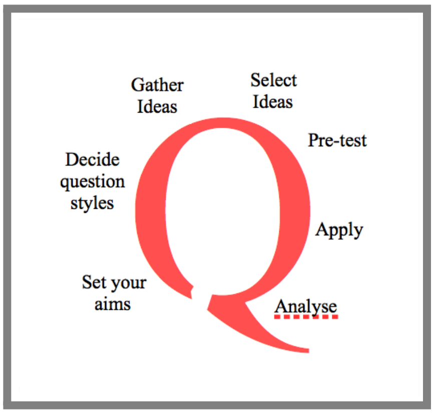
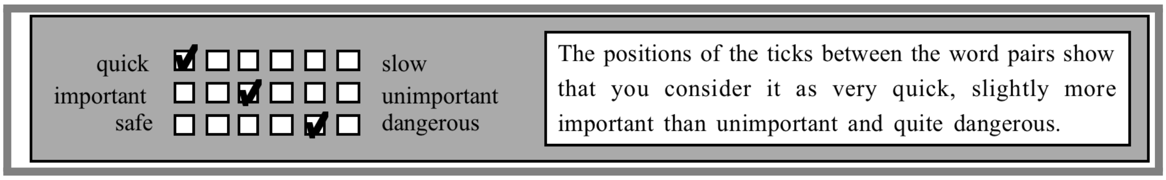


Figure (6.2): *General guidance for preparing a questionnaire.*

In the questionnaire developed for this study, some questions followed the work of Likert (1932), using a five point scale, with students responding using '*strongly disagree*', '*disagree*, '*neutral*', '*agree*', '*strongly agree*' to various statements related to the issue being explored.

The second style of questions followed Osgood *et al.* (1957) who developed a useful approach by placing adjectives or adjectival phrases at opposite ends of a set of boxes. Students were asked to tick the box which best reflected their view. Instructions were given to the students and these are shown with an example from the literature:

Here is a way to describe a racing car.



Use the same method to answer the following questions

What are your opinions about your school laboratory experiences in chemistry?
Tick ONE box on each line.

Useful	☐	☐	☐	☐	☐	☐	Useless
Not helpful	☐	☐	☐	☐	☐	☐	Helpful
Understandable	☐	☐	☐	☐	☐	☐	Not understandable
Satisfying	☐	☐	☐	☐	☐	☐	Not satisfying
Boring	☐	☐	☐	☐	☐	☐	Interesting
Well organised	☐	☐	☐	☐	☐	☐	Not well organised
The best part of chemistry	☐	☐	☐	☐	☐	☐	The worst part of chemistry
Not enjoyable	☐	☐	☐	☐	☐	☐	Enjoyable

(Shah *et al.*, 2007)

Alongside these two types of questions, there are four questions where students were asked to select preferred answers from provided lists. These questions considered their intended subject disciplines, the purpose of laboratory work in physics, differences between university and school laboratories, and more about the way practical physics was offered at school. There is one open question about experiments in the first semester.

The following key themes were investigated in the survey to explore students' perceptions of physics laboratories in school and at university:

1. Understanding the theory of the experiment.
2. Organisation of experiment.
3. The clarity of aims and procedure of experiment in the instruction sheets.
4. Their feelings about working in a group.
5. The extent of linkage between experiments and the relevant theory.
6. Purpose of the laboratory work in their view.
7. Their perceived confidence in carrying out the experiment.
8. The actual experiments: useful, enjoyable, interesting, and helpful?
9. Any differences between university and school laboratory work.

Then, the questionnaire was translated into Arabic language, and the clarity of the Arabic was checked by a professional Arabic speaker.

The questionnaire was applied to first semester student at the beginning of the first semester (when they had just enter university from school). Another questionnaire was used at the end of first semester with the same sample. Many questions were the same in both questionnaires while a few were different. This allowed some useful comparisons to be made. This work was carried out during the Spring 2009 semester in the general physics laboratory at Sebha University, the full questionnaires of this stage being shown in Appendices A.1.1 and A.2.1.

6.3 Second Stage

After reviewing the results from the first stage, the decision was taken to use new approaches in the learning in the laboratory, with the aim to make it more effective for understanding physics. The new approaches involved pre-laboratory exercises before doing the actual experiments and post-laboratory exercises after completing the experiments. Surveys were then used to measure Libyan students perceptions of their university physics experiments. Understanding was measured by looking at performance in the post-laboratory exercises. In this chapter, details will be given about pre-lab and post lab exercises as well as the surveys used.

The second stage was to look at fifth semester physics undergraduates at Sebha University as this gave a good number of students to see how they have perceived their experiments in practical physics. The focus at the second stage is on the effectiveness of the pre-laboratory exercises. Previous work had shown clearly the power of pre-laboratory exercises on increasing learning in inorganic chemistry (Johnstone *et al.*, 1994) and also in developing positive attitudes towards laboratory work.

In the Department of Physics at Sebha University, there were no pre-laboratory exercises in any laboratories courses. It was decided to consider the laboratory course in optics as this gave a good number of students as mentioned above. The student group was divided into two groups, one group worked without pre-laboratory exercises while the other group worked with pre-laboratory exercises. The distribution of students into groups was random.

The aim was to make comparisons between the two groups, to see the effect of the pre-laboratory exercise on the perceptions of the students, and the students' perspectives regarding the use of pre-laboratory exercise in helping with their success in laboratory work. The second stage was carried out during the autumn 2009 semester, in optics physics laboratory at Sebha University.

The focus in this stage was more on the use of pre-laboratory exercises which were given to students one week before doing actual experiment, although very short post-laboratory exercises, involving only two or three questions, were also employed.

List of experiments used for second study:

1. Determination of the reflective index of a glass prism using a spectrometer.
2. Determination of the wavelength of sodium light by using Newton's Rings.
3. Determination of wavelength of light from the helium neon laser by using diffraction grating.
4. Rotation of the plane of polarisation with sugar solutions.
5. Determination of the inter-atomic (or ionic) distances in a solid by using X-ray.

6.4 Third Stage

The third stage was carried out during the Autumn 2010 semester in the optics physics laboratory at Sebha University. The pre-laboratory exercises were used again and post-laboratory exercises were developed considerably (25 minutes for each one after finishing the experiment). Furthermore, the entire set of student instruction sheets were re-written in the third stage. The aim in doing this was to make the entire laboratory experience a cohesive programme as recommended by Carnduff and Reid (2003). However, another aim was to ensure that working memory overload was minimised. Pre-laboratories were known to help in this (Zaman *et al.*, 1998) but the instructions sheets also needed to be re-cast to reduce working memory overload.

The third stage was again to look at fifth semester physics undergraduates at Sebha University. However, the sample was not the same as the one which contributed in the second stage. There were several reasons in continuing with the optics laboratory in the third stage. It allowed comparisons with the previous findings, showing the effects associated with the changing use of pre-lab and post-lab exercises, as well as the recasting of instruction sheets for all experiments. In each stage, no student had met pre-labs or post-labs before undertaking the optics laboratory course.

Again in this stage students were divided into two groups, one group worked without pre-laboratory exercises while the other group worked with pre-laboratory exercises. The distribution of student into groups was random.

The aim was to make comparisons between two groups, to see the effect of the pre-laboratory exercise on the perceptions of the students, and the students' perspectives regarding the use of pre-laboratory exercise in helping with their success in laboratory

The list of experiments for the third stage:

1. Determination of the reflective index of a glass prism using a spectrometer.
2. Determination of the wavelength of sodium light by using Newton's Rings.
3. Determination of wavelength of light from the helium neon laser by using diffraction grating.
4. Rotation of the plane of polarisation with sugar solutions.

It should be mentioned that the fifth experiment which was used in the second stage was removed from the list of the experiments for technical reasons (the equipment was giving problems).

Furthermore, at the end of this stage, semi-structured interviews were carried out with university teachers to explore the views of university teachers related to physics laboratories in Libya as mentioned in the introduction.

The interviews focused on three themes:

- Laboratory physics;
- Pre-laboratory exercises;
- Post-laboratory exercises.

A typical questions of the interviews is shown in the Appendix H

Overall, the following materials were developed:

6.5 Material Developed

6.5.1 Pre-laboratory Exercises

A set of pre-laboratory exercises for each experiment was developed. The aim for these was to prepare the mind for learning and to minimise pressure on the working memory during the conduct of the experiment.

The pre-laboratory exercises were given to students one week before doing the experiment. Checks were made to ensure that they were completed.

Pre-laboratory exercises were first tested by Johnstone (see Johnstone *et al.*, 1994; Zaman *et al.*, 1998) after it was noticed that the information processing model of learning predicted that pre-learning would enhance understanding, because pre-learning enabled more links to be made in long-term memory and also it would reduce working memory overload.

In the context of laboratories, the pre-laboratory exercises could serve many specific functions in achieving these predicted goals. Carnduff and Reid (2003) summarised these:

- *"Ensure that background information is recalled.*
- *Connect and revise prior knowledge.*
- *Provide some reassurance to the student about their grasp of the topic.*
- *Check that any procedures have been read and understood.*
- *Practice appropriate data handing, drawings or calculation.*
- *Lead the student into thinking about the procedure or concepts.*
- *Involve the student in planning.*
- *Connect the experiment with other parts of the course.*
- *Relate the experiment to the outside world.*
- *Improve motivation and, perhaps, invite a prediction or offer a challenge."*

Of course, studying the laboratory manual in advance might help. However, the pre-laboratory exercises specifically allowed underpinning theory to be revised, as well as making the students familiar in advance of how the measurements would be made, the terminology to be used and possible safety hazards. Underpinning all this was the aim to allow students to think about the procedures and concepts involved as well as revising prior knowledge. Thus, the pre-laboratory could be considered as a bridge between lecture and laboratory, experiment and application.

6.5.1.1 Development of Pre-laboratory Exercises

To prepare or to write pre-laboratory exercise requires some care. The specific aims of each experiment need to be known clearly. In addition, the author should have good idea about the prior knowledge (such as concepts, facts, terminology) and appropriate links to this knowledge. The figure below 6.3 shows the needs of the writer to know before attempting to write pre-laboratory exercise.

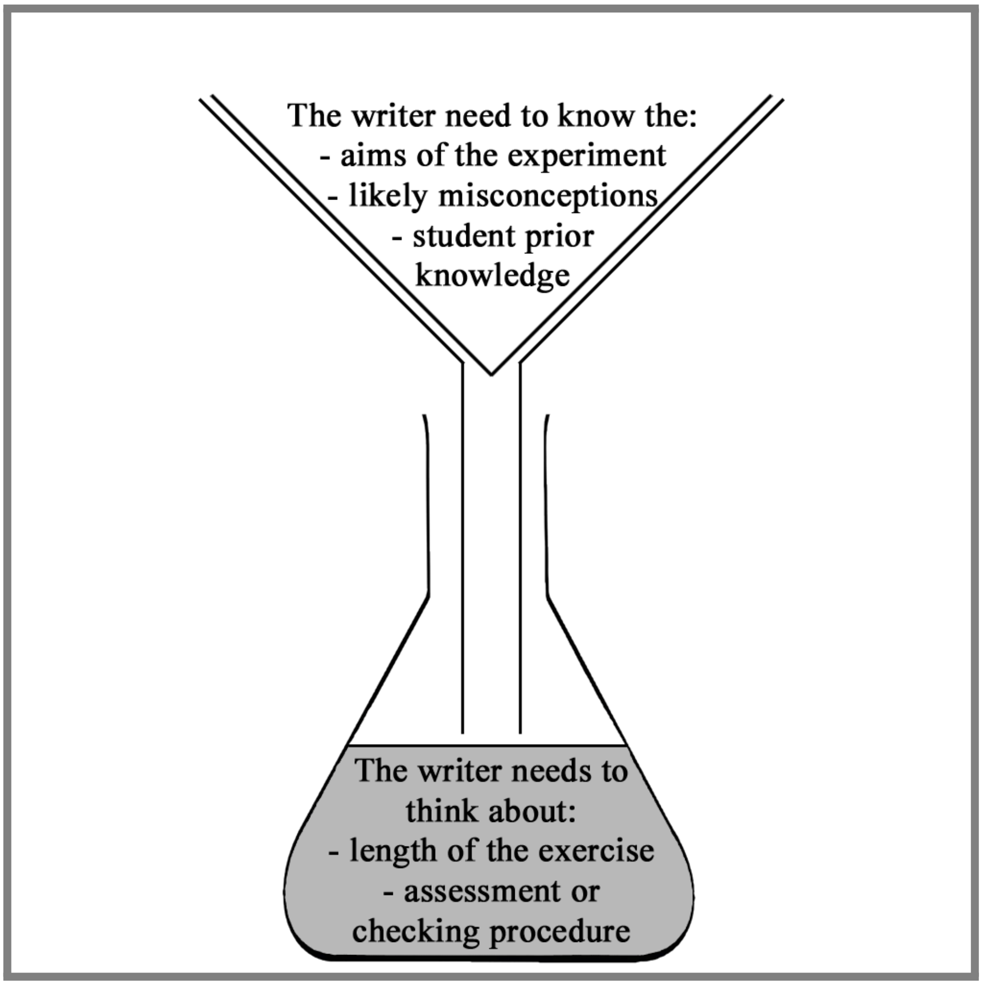


Figure (6.3): *Advice to the writer of pre-laboratory exercise. (Carnduff & Reid, 2003)*

The length of the exercises is important; there needs to be enough time to generate adequate preparation but not so long that the task is burdensome. Carnduff and Reid (2003) emphasised that the procedure for assessment or checking needs to be thought through carefully. Overall, pre-laboratory exercises are not difficult for the professional to prepare, are not expensive, but the evidence shows that they can be a powerful aid to understanding (Johnstone *et al.*, 1994, 1997). However, all the evidence in the literature relates to one Western country (Scotland) although pre-labs are now used in several countries in the West. The real question is whether they would work in the very different educational setting of Libya. The pre-laboratory exercises are shown in full in Appendices B.1.1, B.2.1, B.3.1, B.4.1, B.5.1, C.1.1, C.2.1, C.3.1 and C.4.1

Students perceptions were measured using a questionnaire, while student performance was measured by marking the post-laboratory exercises.

6.5.2 Post-laboratory Exercises

A set of post-laboratory exercises for each experiment was developed. The first set which was used in the second stage were very limited in scope while, in the third stage, they were considerably enhanced. The aim for these was to allow students to apply what they had learnt in the laboratory. The exercises in stage three lasted for about 25 minutes.

Post-laboratory exercises were introduced at the end of each experiment, the purpose of these being to let students review their work and apply their understandings. However, the post-laboratory exercises served another useful function in that they gave evidence about the level of understandings achieved by students. This allowed comparisons between groups (with and without pre-laboratory exercise, and also between male and female in pre-laboratory exercise group).

Post-laboratory exercises offer an opportunity to link the ideas learnt in the actual laboratory to ideas previously learnt. This may lead to richer connections between ideas held in long-term memory. The post-laboratory exercises are shown in full in Appendices B.1.2, B.2.2, B.3.2, B.4.2, B.5.2, C.1.3, C.2.3, C.3.3 and C.4.3. In addition to above, rewritten instruction sheets were added in the third stage.

6.5.3 Completely Re-cast Instruction sheets

Re-cast instruction sheets were used only in stage three and they aimed to make the entire learning experience cohesive, simplify the instructions, and reducing working memory overload.

In the physics department laboratory, students are given an instruction sheet at the beginning of the laboratory work after a short talk given by demonstrators. The students are required to follow these instruction sheets step by step to finish the experiment. The danger with this approach is that it can reduce the laboratory experience to students following a recipe. Johnstone and Letton (1991) noted that the experimental instructions along with the observational load encountered by students in the laboratory generated information overload. Students then tend to follow the manual without any understanding. Johnstone and Letton (1991) stressed the vital importance of '*reducing the noise*' in preparing such instruction sheets. Later, Johnstone *et al.* (1994) observed that most students follow instructions in the laboratory manual without understanding what they are doing.

In re-writing the instruction sheets, the advice of Johnstone and Letton (1991) was followed carefully. In addition, it was found that some of the currently used instruction sheets lacked key important information.

At the start, while preparing the revised instruction sheets, a clear aim for each experiment was identified and articulated. Moreira (1980) found that in many cases students carried out the experiments without clear ideas about what they are doing or what lay behind the experiment. Moreira pointed out that many students cannot identify the basic concepts or phenomena of the experiments. Thus, the student has no clear idea about concepts and phenomena underpinning the experiment and, thus, he or she may well not understand the experiment, the rewritten instruction sheets being shown in full in Appendices C.1.2, C.2.2, C.3.2 and C.4.2.

6.5.4 Surveys

It was decided to use questionnaires to collect data also for second and third stage. After finishing each experiment, this offers an overview of students self-perception of the experiment which they have just finished. The questionnaire offers a powerful way to obtain large data quickly (Best, 1981; Gay & Airasian, 2000; Fraenkel & Wallen, 2000). The approach to questionnaire construction again followed the guidance given by Reid (2006): see Figure 6.2.

As before, some questions in the questionnaire for the second and third stages followed the approach of Likert (1932), while others followed Osgood *et al.* (1957). There were also rating questions. The following key themes were investigated in the survey to explore student perceptions of university physics laboratories and to check the effectiveness of pre-laboratory exercise:

- Motivation and interest.
- Understanding the theory of the experiment.
- Preparation for the experiment.
- Organisation of the experiment.
- The clarity of aims, and procedure of the experiment.
- Apparatus used are difficult or easy.
- Their feelings about working in a group.

Then, the questionnaire was translated into Arabic, and the clarity of the Arabic was checked by professional Arabic speaker as it was done in the first stage.

It is also important to mention that the same questionnaire used in this study for both experimental groups (who worked with pre-laboratory exercise) and control group (who worked without pre-laboratory exercise). This allowed comparisons between groups. The full questionnaires are shown in Appendices D.1 and D.2

6.6 Statistical Treatment of the Data

Some statistical tests were used in order to make objective judgements from the questionnaires. The SPSS package was used to analyse the data obtained from the survey. The frequencies of student responses were summarised, groups (with and without pre-laboratory exercises) were compared to each other by using chi-square (χ^2) to check statistical significance. Differences between male and female responses were also compared in each group.

Chi-square is a non-parametric test that handles comparisons between sets of frequencies. The data may Bo ordinal or categorical and no distribution is assumed. The normal limitations for the use of chi-square were applied: where numbers in a category were low, grouping was applied and the degrees of freedom adjusted accordingly. Typically, a minimum category level of 5% is required although some authors make more demanding conditions. For a useful discussion of the use and misuse of chi-square, Lewis and Burke (1949) offered guidelines, which were followed here. This was followed up much later by Delucchi (1983).

Chi-square (χ^2) was applied as a '*goodness of fit*' to judge the significant differences in responses of different groups. For example, it was possible to see, on each question, whether group with pre-laboratory exercise was giving a different pattern of responses when compared with a group without pre-laboratory exercise. Chi-square (χ^2) was also used as a '*contingency test*' to compare between male and female of each group. The two methods of calculation of Chi-square (χ^2) are discussed in Appendix F.

The questions in Likert format gave data on a five point scale while the questions in the Semantic Differential format used a six point scale. However, for clarity and simplicity, the data will be presented on three point scale here, with data shown as percentages. Although the data are grouped into three categories for clarity, the statistical calculations used the raw data in as many categories as possible (to satisfy the limiting conditions for use of chi-square).

The following methods are employed:

One example will be discussed. The responses of the student will either be in negative response or positive response, or neutral response.

N		*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
	Code used >>>	5	4	3	2	1
Question >>>	This experiment was easy to do					

The response of this question will be positive response if he or she chooses " *strongly agree*" or "*agree*" while, "*disagree*" or "*strongly disagree*" represent negative response, but, if students choose neutral, that mean in neutral response or "*uncertain*". This allows the results to be presented as in the table above.

Also, in the questionnaire, there are some questions from 'Osgood' type questions (six point scale). In order to understand how the data was treated, one example will be discussed.

useful ☐ ☐ ☐ ☐ ☐ ☐ *useless*

In the semantic differential format in this example, the negative statement is at the right side of the questionnaires and the positive statement is at the left side. In this case the first two boxes from the right represent negative response whereas the first two boxes from left represent positive response. The other two boxes in the middle represent neutral response. Thus, if a student chooses the third box from the right, that means he has chosen a neutral response. This allows the results to be presented as in the table above.

In addition to the above, the t-test was used to compare the students' scores in the post-laboratory exercises. The t-test is used to compare the means of two groups to see if they are statistically different from each other. This analysis is appropriate whenever you want to compare the means of two groups, provided that the data are integer and approximately normally distributed.

The statistic can only be applied to sets of integer data which are approximately normally distributed as mentioned above. Thus, it can be used to compare marks in tests and examinations or the marks obtained by men and women. The specific test used depends on the samples involved. In the study here, the samples are independent samples and the independent samples t-test was used. The t-test is part of the ANOVA group of tests of significance but its used is confined to the comparison between two samples.

6.7 Study Sample

For the first stage, the sample consisted of first semester undergraduate students in the Science Faculty at Sebha University. In the second and third stage, the sample was from fifth semester undergraduate students in the Physics Department at Sebha University. Below are some information about the university: Sebha University is located in the city of Sebha south of Libya. Sebha University awards Bachelor's degrees from these faculties:

- Agriculture.
- Education, Arts and social Science.
- Economics and Accountancy.
- Engineering.
- Law.
- Medicine.
- Physical Education.
- Science.

In addition, the university awards Master degree in specific fields:

- Chemistry.
- Biology.
- Arabic language studies.
- History.
- Philosophy.
- Islamic studies.

The academic year at the university runs from September to July through two semesters. The university is fully funded by the Ministry of Higher Education and hence it provides free education for all students. The number of students at Sebha University is approximately 14000 students (National Committee for Universities, 2010). The university is typical example of a Libyan university in terms of size, range of subjects taught and the type of students who attend.

6.7.1 Sample of First Stage

One hundred and fifty students from the first semester contributed in the first stage. This sample was chosen randomly from the list of first semester students. The number of students participating represented 60% of the total students and they were surveyed twice. Firstly, at the beginning of their university studies (not long after completing secondary school). This group was considered the '*school sample*'. Secondly, the sample was surveyed again at the end of their first semester and they were considered the '*university sample'*. The results from the school group and the university group were compared.

6.7.2 Sample of Second Stage

The fifth semester undergraduate students conducting optics laboratory work were chosen as the sample of the second stage. In total, ninety-five students participated. Targeted students had to be in their fifth semester as this is the group who chose physics and had the laboratory where there were problems. Some of them worked with pre-laboratory exercise while others worked without pre-laboratory exercise. Figure 6.4 shows how the sample was organised.

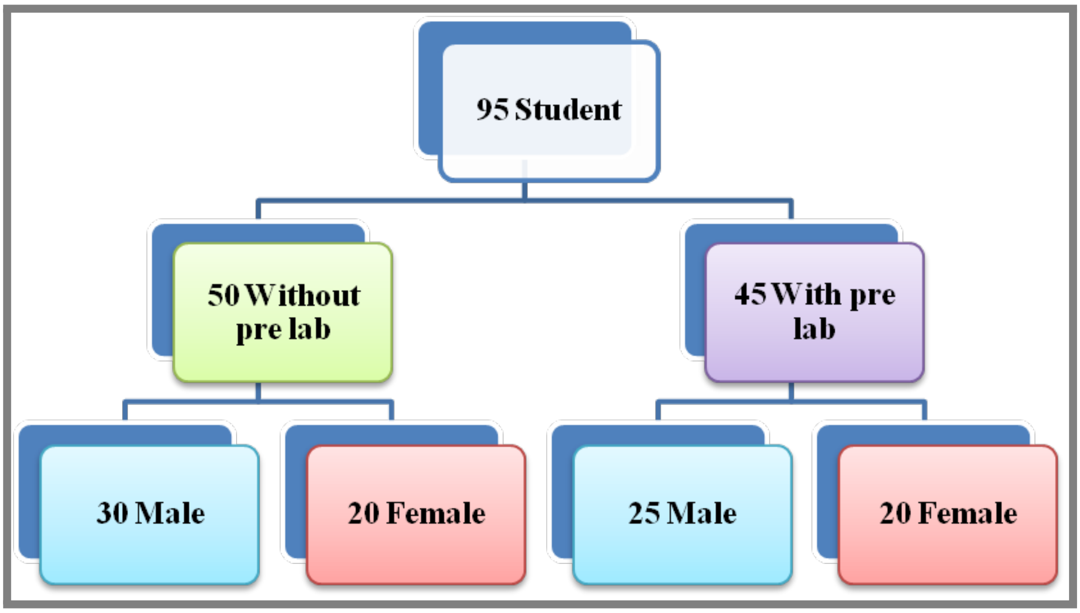


Figure (6.4): *The sample of the second stage*

Five experiments from the fifth semester laboratory work were chosen for this research. Fifty students worked without pre-lab for just two experiments and forty five students worked with pre-lab for just three experiments, then these two groups were interchanged, fifty students worked with pre-lab for the other three experiment while forty five students worked without pre-lab for the first two experiments (experiment which were used in this stage are mentioned in section 6.3).

6.7.3 Sample of Third Stage

The fifth semester undergraduate students conducting optics laboratory work were chosen as the sample of the third stage. The reason for the choice is the same as the one mentioned in the second stage sample. In total, 106 students contributed in the third stage, some of them worked with pre-laboratory exercise while others worked without pre-laboratory exercise. More details about the third stage sample are shown in Figure 6.5.

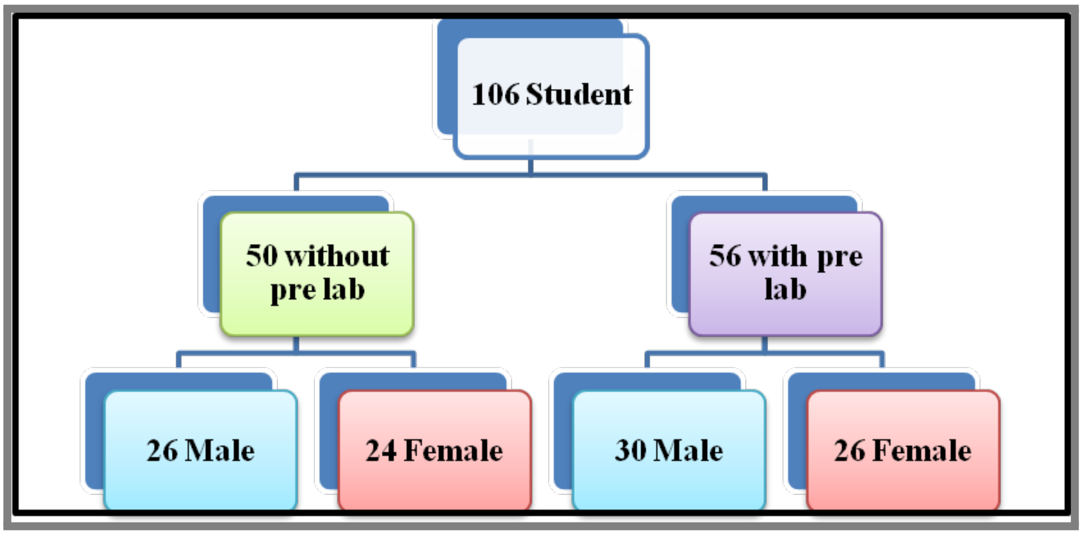


Figure (6.5): *The sample of the third stage*

The sample above carried out four experiments from fifth semester laboratory work, chosen for the third stage in this research. Fifty students worked without pre-lab for the first two experiments and fifty six students worked with pre-lab for other two experiment. Then the two groups interchanged: fifty students worked with pre-lab for the last two experiment while fifty six students worked without pre-lab for the first two experiments.

In addition, semi structure interviews were carried out with ten university teachers who taught in the laboratories where the study took place. All of the interviewees hold doctorates in physics and they were chosen from a number of laboratory teachers due to their previous experience in teaching the optics laboratory.

The following chapter presents the data gathered and discusses its interpretation. The data are shown in full in Appendix A.1.2, A.2.2, B.1.3, B.2.3, B.3.3, B.4.3, B.5.3,C.1.4, C.2.4, C.3.4, and C.4.4.

Chapter 7

Data Analyses (First stage)

7.1 Introduction

In this chapter, the data from the questionnaires in the first stage will be summarised and discussed. This involves the questionnaires which were used with first semester students at the beginning of their study at university to investigate their perceptions of physics laboratories in school, as well as the questionnaires used at the end of the first semester to establish an overview of their perception of physics laboratory work at university in order to identify areas where support is needed.

For each question, a table will show the percentages of students who are in each category: positive response, neutral response, or negative response, as discussed in the last chapter. This data will also be summarised in graphical form in some cases. Where the same questions were used in both questionnaires, responses patterns will be compared between the two groups (start of semester, end of semester) to see where there are significant changes. The comparison will use chi-square as a test of goodness of fit, with the 'start of semester' data acting as the control.

The sample involves 150 students, 60 male, 90 female. The results from each question are now discussed in turn. The data are presented as percentages for clarity but all statistical analyses use frequency data, using the full range of responses. The first section looks at the data from the school (start of semester) group.

7.2 Results from school (start of semester) group

7.2.1 Desired Degree

Q2 What degree do you intend to study at university?

☐ Physics ☐ Mathematics ☐ Computer science ☐ Statistics

This question was given to the students only in the start of semester questionnaire:

Table (7.1): *The students desired degree*

Discipline	Percentage
Physics	21
Mathematics	21
Computing Science	40
Statistics	18

It is clear that the majority of the students are intending to study for degrees other than physics and, therefore, the physics course is taken here as an outside subject. This is similar to a previous finding (Ali Hamed, 2005).

7.2.2 Experiences in Practical Physics Work

Q3 Think about your experiences in practical Physics work

The responses in this will reflect their experiences in school physics (Table 7.2).

Table (7.2): *Experiences in Practical Physics Work*

	Statement	Positive	Neutral	Negative
1	Prefer to have written instructions for experiments	70	8	22
2	Practical work helps my understanding of Physics topics	38	7	55
3	Discussions in the laboratory enhance my understanding of the subject	65	10	25
4	I felt confident in carrying out the experiments in Physics	44	15	41
5	The experimental procedure was clearly explained in the instructions given	46	11	43
6	I was so confused in the laboratory that I ended up following the instructions without understanding what I was doing	65	9	26
7	There was good linkage between experiments and the relevant theory	68	11	21

Nearly three quarters of students prefer to get written instruction for experiments and felt that the experimental procedure was clearly explained in instructions given but perhaps they had no other experience of any alternatives. Although more than three fifths of them have positive opinions about discussions in laboratory, they expressed their confusion in the laboratory in following instruction sheets without understanding what they are doing. Nonetheless, more than three fifths of them see there was good linkage between experiments and the relevant theory. This is easier in a school situation. On the other hand, less than half of the sample said that practical work helped them to understand physics topics or that they felt confident in carrying out the experiments in physics.

7.2.3 Experiences of Practical Work in Physics at School

Q4 What are your opinions about your experiences of your practical work in physics at school? (Tick ONE box on each line)

The responses are:

Table (7.3): *Experiences of Practical Work in Physics at School*

Statements	Positive	Neutral	Negative
1- This practical is useful.	41	32	27
2- This practical is helpful	47	23	30
3- This practical is understandable.	40	22	38
4- This practical is interesting.	44	27	29
5- This is the best part of Physics.	29	29	42
6- This practical is enjoyable.	44	23	33

It is clear from the table above that the students have a fairly negative perspective of the physics laboratory in that less than half of the sample expressed that: the physics practical is useful, helpful, understandable, interesting, and enjoyable. Perhaps of great importance, just third of the sample see physics practical is the best part of physics, much less than other surveys (Reid & Skryabina, 2002; Sneddon *et al.*, 2009).

7.2.4 Why Laboratory Work is an Integral Part of Physics Course

Q5 Here are several reasons why laboratory work is an integral part of Physics course.

Pick the three which you consider to be important and rank them in descending order of importance

1. Physics is a practical subject.
2. New discoveries are made by means of experiments.
3. Experiments illustrate theory.
4. Experimental skills can be gained in the laboratory.
5. Laboratory work allows me to test out ideas.
6. Experimental work allows me to think about Physics.
7. Experiments assist me to planning and organise.
8. Experimental work makes Physics more enjoyable.

The response pattern is:

Table (7.4): *Why laboratory work is an integral part of Physics course*

Statements	Percentage
1- Physics is a practical subject.	76
2- Experiments illustrate theory for me.	26
3- Laboratory work allows me to test out ideas	20
4- Experiments assist me to planning and organise	15
5- New discoveries are made by means of experiments.	27
6- Experimental skills can be gained in the laboratory.	61
7- Experimental work allows me to think about Physics.	43
8- Experimental work makes Physics more enjoyable.	31

In the table above, the percentage figures are obtained by adding the percentage of the students' choices for each statement as 1st, 2nd, or 3rd choice. The first chosen reason are highlighted in red, the second are highlighted in orange, and the third are highlighted in green. The most popular is shown in red and reflects a common view. However, the fact that physics is a practical subject does not necessarily require that it is taught using the laboratory. This choice is amplified by the second choice. The actual experimental skills are irrelevant to the nearly 80% who will leave physics to pursue other subjects for their degrees. The third choice is much more important for physics, like any science, gains its understandings by means of the experimental. The response patterns reveal inadequate insights and may reflect the way lab work is being employed at school level.

7.2.5 University and School Laboratory Work, and their Aspirations

Q6 In what ways do you think university practical work will differ this year from the practical work you experienced at school? (Choose up to three answers)

- Use of more complicated equipment.
- Use of modern equipment.
- I will get less guidance than at school.
- I will have more choice in the experiments I do.
- I will have more time for each experiment.
- I will do the experiments myself instead of watching them being done.

The response pattern is:

Table (7.5): *University and school practical work.*

Statement	Percentage
1- Use of more complicated equipment.	26
2- I will get less guidance than at school.	25
3- I will do the experiments myself instead of watching them being done.	80
4- I will have more choice in the experiments I do.	50
5- Use of modern equipment.	53
6- I will have more time for each experiment	65

One response stands out (red). They expect to do more themselves and perhaps this is reflection of lack of such opportunity at school. They also expect more time, and this also may reflect the lack of laboratory work at school. Their aspiration for more choice in experimental work is unrealistic but they do expect more modern equipment. It is possible that this message reflects the lack of such equipment at school.

Q7 Are you looking forward to the practical work this year?

Very much □ □ □ □ □ □ Not at all

The response pattern is:

Table (7.6): *Student's aspiration about university physics laboratory work*

Question	Positive	Neutral	Negative
I am looking forward to the practical work this year	61	24	15

Despite slightly negative opinions towards practical physics work in school, students are looking forward to physics practical work at university.

7.2.6 Practical Physics Experience at School

Q8. Which of the following would best describe your practical physics experience at school?

(a) I carried out some of my experiments by myself.

(b) Most of my experiments were done as computer-based simulations.

(c) My teacher carried out most of my experiments as demonstrations.

(d) I did most of my experiments myself, either alone or in groups.

The response pattern is:

Table (7.7): *Students' description of their practical physics experience at school*

Statement	Percentage
I carried out some of my experiments by myself.	4
Most of my experiments were done as computer-based simulations.	0
My teacher carried out most of my experiments as demonstrations.	68
I did most of my experiments myself, either alone or in groups.	28

More than two thirds of the students described their practical physics experience at school as their teacher carrying out most of their experiments as demonstrations. This perhaps explains their desire for more '*hands-on*' experience at university.

7.2.7 Summary

The overall pattern, showing their reactions to school physics laboratories, is:

- Students prefer written instructions for experiments.
- They see discussions in the laboratory enhancing their understanding.
- They want instruction sheets but they are still confused in what they do.
- There was a good linkage between experiments and the relevant theory.
- Few students think that practical work is useful, helpful, interesting, understandable, and as a best part in physics.
- Three reasons why laboratory work is an important part of Physics course stand out:
  1. Physics is a practical subject.
  2. Experimental skills can be gained in the laboratory.
  3. Experimental work allows me to think about Physics.
- The three top differences between University and school practical work are:
  1. I will do the experiments myself instead of watching them being done.
  2. I will have more time for each experiment.
  3. Use of modern equipment.
- Most laboratory work is demonstrated at school by teachers.

This offers a picture of the school laboratory scene in physics. The next section looks at some comparisons between school and university physics.

7.3 Comparisons Between School and University Students Perceptions

7.3.1 Experiences in Practical Physics Work

The students from both groups were asked to think about their experiences in practical physics. The responses of school and university group now compared in the table below:

Table (7.8): *Experiences in practical Physics work*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*I prefer to have written instructions for experiments*						
University group	150	73	7	20	0.9	4	ns
School group	150	70	8	22			
Q1 (b)	*Practical work helps my understanding of Physics topics*						
University group	150	34	11	55	3.9	4	ns
School group	150	38	7	55			
Q1 (c)	*Discussions in the laboratory enhance my understanding of the subject*						
University group	150	70	8	22	2.4	4	ns
School group	150	65	10	25			
Q1 (d)	*I felt confident in carrying out the experiments in Physics*						
University group	150	52	12	36	13.7	4	< 0.05
School group	150	44	15	41			
Q1 (e)	*The experimental procedure was clearly explained in the instructions given*						
University group	150	31	14	55	14.8	4	< 0.01
School group	150	46	11	43			
Q1 (f)	*I was so confused in the laboratory that I ended up following the instructions without understanding what I was doing*						
University group	150	63	12	25	1.1	4	ns
School group	150	65	9	26			
Q1 (g)	*There was good linkage between experiments and the relevant theory*						
University group	150	36	15	49	94.4	4	<0.001
School group	150	68	11	21			

The first semester students were questioned when they had just entered University, their views at that time is reflecting school experience. When questioned at the end of the first semester, their views reflect their university experience. Thus, the comparison in the table above illustrates how their views have altered as a result of their university experiences during their first semester in physics.

7.3.2 Experiences of Practical Work in Physics at University and School

The students from school and university were asked to express their opinions about experiences of practical work in physics at University and school, giving the following data:

Table (7.9): *Experiences of practical work in physics at University and school*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is practical work useful*						
University group	150	41	31	28	0.5	5	ns
School group	150	41	32	27			
Q2 (b)	*Is practical work helpful*						
University group	150	45	25	30	0.3	5	ns
School group	150	47	23	30			
Q2 (c)	*Is practical work understandable*						
University group	150	38	22	40	3.3	5	ns
School group	150	40	22	38			
Q2 (d)	*Is practical work interesting*						
University group	150	44	27	29	0.1	5	ns
School group	150	44	27	29			
Q2 (e)	*Is practical work the best part of physics*						
University group	150	27	29	44	0.5	5	ns
School group	150	29	29	42			
Q2 (f)	*Is practical work enjoyable*						
University group	150	56	21	23	1.0	5	ns
School group	150	44	23	33			

Both groups show similar views. On balance, they tend to see practical work as useful, helpful, interesting and enjoyable, although quite large minorities are negative in these areas. However, they are very ambivalent that it is understandable, and the majority does not see practical work as the best part of physics. Given the universal popularity of laboratory work in most countries (Reid & Skryabina, 2002), this suggests that the provision in Libya does need some attention.

7.3.3 Why Laboratory Work is an Integral Part of Physics Course?

Students were asked to tick three reasons for why laboratory work is an integral part of physics course, the responses of the two groups being shown in the Table 7.10.

Table (7.10): *Comparison: why laboratory work is part of a Physics course*

No.	Statement	University group	School group	χ^2	p
1	Physics is a practical subject	75	76	0.2	ns
2	Experiments illustrate theory for me	26	26	0.0	ns
3	Laboratory work allows me to test out ideas	0	20	*	
4	Experiments assist me to planning and organise	41	15	74.2	< 0.001
5	Discoveries are made by means of experiments	36	27	6.8	< 0.01
6	Experimental skills can be gained in laboratory	53	61	4.8	< 0.05
7	Experimental work allows me to think about Physics	40	43	0.7	ns
8	Experimental work makes Physics more enjoyable for me	31	32	0.0	ns

$*$ *Cannot be computed legitimately*

While the '*top three*' are the same, there are some quite significant differences in perspectives. After a semester of university physics, the students are much more aware of the importance of being able to test out new ideas. However, they are less convinced about making new discoveries and they very much less convinced about planning and organising. It seems that the university laboratory experience has placed a very tight set of restrictions on freedom; the students have to follow the prescribed instruction sheets.

7.4 Experience in the First Semester Experiments

One more question was used only in the second questionnaire to university groups. The aim of this question was to explore their experience in each of the first semester experiments.

Please answer the following questions in terms of your experiences in this semester only.

Q5 Think back over the experiments which you have completed during this semester.

a) Which experiment did you find most useful or enjoyable?
b) What was it about that experiment that made it particularly useful or enjoyable?
c) Did you find the experiment easy or challenging?
d) What did it teach you?
e) List any skills which improved as a result of doing the experiment.

The three (out of ten) most useful or enjoyable experiments are shown in Table 7.11.

Table (7.11): *Experiments which considered by students as useful and enjoyable*

The name of the experiment	Percentage
1- Determination of the viscosity of oil.	50
2- Determination of acceleration of gravity by using simple pendulum.	30
3- Verification of Ohm's law, and law of connecting resistances.	20

In considering the reasons for this, the most common comments from the students are:

1. Related to my life:
   - Determination of the viscosity of oil 40%.
   - Determination of acceleration of gravity 25%.
2. Belongs to subject which I like.
   - Determination of the viscosity of oil 10%.
3. It was easy experiment:
   - Determination of acceleration of gravity 30%.
   - Verification of Ohm's law, and verification of the law of connecting resistances 15%.
4. I worked with good group:
   - Determination of the viscosity of oil 10%.
   - Verification of Ohm's law, and verification of the law of connecting resistances 20%.
   - Determination of acceleration of gravity 15%.
5. I got good result.
   - Determination of the viscosity of oil 10%.
   - Determination of acceleration of gravity 40%.
   - Verification of Ohm's law, and verification of the law of connecting resistances 35%.

For the first experiment, the majority of the students believe that the experiment is not easy but challenging. For the second experiment, nearly half of students believe that taking the observations are easy, but to draw the graph was not easy.

In looking at what they considered they had learnt from each experiment, they drew attention to:

- How to take the observations.
- How to be careful while working with electricity:
  (a) To avoid the damage of instruments, because high voltage it could damage the low voltmeter and Ammeter range.
  (b) To avoid harm ourselves.
- How to draw graph.
- Now I have met new equipment.
- How to work with the new equipment.

7.4.1 Summary

At the end of the semester, the university students were asked an extra question in the second questionnaire. Their responses can summarised:

- Table 7.11 presents the top three experiments which were chosen by the students as useful and enjoyable experiments, the reasons being:
  1. Related to my life.
  2. Belonging to topic that are liked.
  3. Being an easy experiment.
  4. Working with a good group.
  5. Giving a good result.

- Students believe they gained some skills and learnt how to make good observations, how to protect themselves from hazards, how to draw graphs, and they were introduced to new equipment.

7.5 Conclusions

In conclusion, the major findings from the first stage can be summarised as follows:

- The students prefer written instruction sheets although they believe they ended up following these instructions sheets without understanding what they were doing. However, they consider these instructions as a survival kit to succeed in this course. The reason for that is there is very few references in Arabic language in the field of physics in general and specially in practical physics. Although the students are taught English at secondary school, their language skills are not yet good enough to be able to access English texts and gain much help from them. The instruction sheets could help them to run their laboratory work more efficiency or it simply may reflect the insecurity that many feel when are not sure what they are to do.
- The practical work seems not to be well established in Libyan schools or universities. It is not yet well organised and does not work very effectively. This is reflected in the data obtained from university and school students on the questions: (Practical work helps my understanding of Physics topics), (I felt confident in carrying out the experiments in Physics), (The experimental procedure was clearly explained in the instructions given),(I was so confused in the laboratory that I ended up following the instructions without understanding what I was doing) (Table 7.8).
- The school group believes that there is a good linkage between experiments and the relevant theory. According to the Libyan physics curriculum at school,

after the teacher finish theoretical lesson, usually the teacher demonstrates the relative experiments to illustrate theoretical lessons. Thus, there is a strong relationship between the laboratory work and their course. Sadly, this means that the experimental is often seen as following theory rather than seeing the way the experimental generates theory. In the first semester at university, there are few linkages between practical work and relevant theory.

- The responses to the questions shown in Table 7.9 express the feeling of many that practical work is not useful, not helpful, not understandable, not interesting, and not enjoyable and not the best part of physics (school and university). These are important more affective aims (Johnstone & Al-Shuaili, 2001), and this identifies that there are problems which need addressed. Thus, Keller (1983) noted that interest for learning activities is very important. If some activity is boring the learner may lose the interest to learn.
- The students seemed to be aware of some reasons why laboratory work is an integral part of physics course, such as: Physics is a practical subject, experimental skills can be gained in the laboratory, and experimental work allows thought about Physics. However, they seem unaware of the way the experimental work generates insights and how the experimental work can make the physics real.
- The students at school are looking forward to practical physics. At school, they tended just to watch teacher demonstrations. Now they want to do it for themselves (see Tables 7.5 and Table 7.7).
- Although the idea of computer-based simulations has considerable potential, the lack of experience, lack of equipment and lack of confidence with teachers meant that the students did not see this as an option.
- The students prefer the experiment which is relevant to their life, challenging, and they prefer to work in groups. This raises interesting questions and is very consistent with the findings of Reid and Skryabina (2002), looking at wider aspects of physics learning. Students are able to distinguish between difficulty and challenge, favouring the latter but not the former.

- According to data obtained, students learnt important issues from practical work such as how to take the observations, how they protect themselves from hazards, how to deal with data such as draw graph. This is consistent with the findings of Carnduff and Reid (2003) as reasons for inclusion of practical work in the undergraduate courses.

The next chapter will describe some steps that were taken to address some of the problems identified in the first stage for university students. The outcomes from these changes, when applied to a physics laboratory in Libya, will be presented and their significance discussed.

Chapter 8

Data Analyses (second stage)

8.1 Introduction

This chapter will describe some steps that were taken to address some of the problems identified in the first stage for university students at Sebha University. The outcomes from these changes, where applied to a physics laboratory in Libya, will be presented and discussed.

In the second stage, it was decided to develop a new approach to make the laboratory experience more effective for understanding physics by testing out some new approaches with university students in a Libyan University. For that purpose, the decision was made to apply pre-laboratory exercises before doing the actual experiments, which are shown in full in Appendices B.1.1, B.2.1, B.3.1, B.4.1 and B.5.1, and to use post-laboratory exercises after completing the experiments. At the end of each experiment, the students were surveyed by using a short questionnaire.

The students were asked to undertake a post laboratory exercise after each experiment to let them review their work. The marks from this were used to see the effect of the pre-laboratory exercises on their learning. The post laboratory exercises and the survey are shown in full in the Appendices B.1.2, B.2.2, B.3.2, B.4.2, B.5.2 and D.1.

In this chapter, the data from the questionnaires which were used at the end of the selected five experiments will be summarised and discussed. For each question, a table will show the percentages of students selecting each of the responses, as discussed in chapter six.

Responses to the questions from both groups (‘*with pre-laboratory group*’ and the ‘*without pre-laboratory group*’) will be compared, using chi-square, to see where there are significance changes. The performances in the post-laboratory exercises will be compared using a t-test, the scores being approximately normally distributed.

Furthermore, comparisons between males and females of ‘*with pre-laboratory group*’ will be made, both with survey questions and with post-laboratory exercises performance. Only the experimental group is considered, the aim being to explore any differences in perceptions with men and women in relation to the introduction of pre-laboratory exercises. The samples are small and chi-square sensitivity is, therefore, low. In all analyses, the actual frequencies were used, grouping where necessary to satisfy the requirements for chi-square.

The sample for the second stage was from third year undergraduate students (fifth semester),The course is their optics practical and the reason for choosing this course is because optics was perceived as difficult topics in Libya (Ali Hamed, 2005). Optics is taught in the fifth semester, with good number in the class as a sample for this research. 95 students were involved at this stage. The experiment was designed in this way. Five experiments from the fifth semester laboratory work were chosen for this stage. 45 students worked with pre-labs for three experiments and the remaining

50 carried out these experiments without pre-labs. For the other two experiments, 50 used pre-labs and 45 did not use pre-labs.

Table (8.1): *Title of selected experiments*

	Title	Description
1	Refractive Indices	The determination of the refraction index of a glass prism using a spectrometer.
2	Wavelength of sodium light	Determination of the wavelength of sodium light by using Newton's Rings.
3	Wavelength of light (helium neon laser)	Determination of wavelength of light from the helium neon laser by using diffraction grating.
4	Rotation of the plane of polarisation	Rotation of the plane of polarisation with sugar solutions.
5	Inter – atom distance	Determination of the inter-atom (or ionic) distances in a solid by using X- ray

The data from each experiment are now discussed in turn. This involves survey questions and the performance in the post-lab exercises. Then, data will be analysed by gender to see if the pre-lab approach is bringing benefits or otherwise equally to men and women.

8.2 First Experiment

8.2.1 Students Opinions about First Experiment

Although previous studies have shown that high levels of reliability are to be expected with questionnaires (Reid, 2003; Reid, 2006; Reid, 2011), the opportunity was taken to look at reliability here (consistency of responses). In question 1, each item was asked in two forms, positive and negative (arranged randomly) and the response patterns for the two versions to each item were examined using chi-square as a contingency test. It was found that no responses differed by more than 2% in any category while every chi-square values was not significant. Thus, question one contains twenty items: ten items are phrased positively which are referred by (a, b, d, k, l, m, n, p, q, and r) while the remaining ten are the negative form. For simplicity, the Tables 8.2, and 8.3 include only the data for the positive questions. The original data discussed in Tables 8.2 to 8.49 were derived from data generated on five and six point scales. In the tables, this has been reduced to three categories, simply for clarity. However, all the chi-square calculations have been calculated based on the original five or six point scales. It is critical in undertaking chi-square calculations that no category falls below five Delucchi, (1983). These data were grouped as necessary and the degrees of freedom fell concomitantly. The approach is outlined in Appendix F.

Table (8.2): *Question (1): Students' opinions about first experiment (a, b, d, k, l)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
With Pre-lab	45	69	0	31	15.0	2	< 0.001
Without Pre-lab	50	42	0	58			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
With Pre-lab	45	73	0	27	19.9	2	< 0.001
Without Pre-lab	50	42	0	58			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
With Pre-lab	45	67	13	20	19.1	3	< 0.001
Without Pre-lab	50	38	10	52			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
With Pre-lab	45	68	5	27	38.6	2	< 0.001
Without Pre-lab	50	28	12	60			
Q1 (l)	*It was easy to follow the laboratory manual*						
With Pre-lab	45	69	0	31	25.5	2	< 0.001
Without Pre-lab	50	34	0	66			

In every item in Table 8.2, the "*with pre-laboratory group*" was very markedly more positive than the '*without pre-laboratory exercise group*'. Thus, the pre-laboratory experience here made the experiment easier, the purpose clearer, and the lab manual was easier to follow. They saw the preparation in advance as helping them to understand better and the whole topic was made more interesting.

Enjoyment and interest are important as Johnstone and Al-Shuaili (2001) have noted. The perceived value of the pre-laboratory is also consistent with the findings of Johnstone *et al.* (1998), specifically in Physics.

From Table 8.3, the majority of the '*with pre-laboratory group*' had finished the experiment within the described time, and felt that the apparatus was easy to use, with ⅔ seeing the preparation making the procedure much clearer. The other group was very much less positive. Carnduff and Reid (2003) note that "*introducing equipment*" and "*developing time management skills*" are key elements in undergraduate courses and the pre-laboratory experiences have helped here

Table (8.3): *Question (1): Students' opinions about first experiment (m, n, p, q, r)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
With Pre-lab	45	73	3	24	57.0	2	< 0.001
Without Pre-lab	50	28	16	56			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
With Pre-lab	45	75	0	25	6.0	2	< 0.05
Without Pre-lab	50	60	0	40			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
With Pre-lab	45	68	7	25	60.3	2	< 0.001
Without Pre-lab	50	26	16	58			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
With Pre-lab	45	49	31	20	12.9	3	< 0.01
Without Pre-lab	50	30	24	46			
Q1 (r)	*The experiment helped me to understand some of the course work*						
With Pre-lab	45	67	11	22	27.8	3	< 0.001
Without Pre-lab	50	36	12	52			

In addition, being able to apply knowledge is important and the pre-laboratory group are much more positive about this. Black and Ogborn (1979) noted the value of the laboratory in terms of "*the illustration of idea of subject*" and the pre-laboratory exercise group saw this much more positively.

Overall, the "*with pre-laboratory group*" are very much more optimistic in every item, especially on the use of apparatus, experimental procedures and understanding course work. However, being able to apply the knowledge in other contexts is not fully developed.

From Table 8.4, the '*with pre-laboratory group*' was very markedly more positive than the '*without pre-laboratory exercise group*' in seeing the experiment as useful and helpful. They were also more positive, seeing the experiment as understandable, and interesting. However, the pre-laboratory experience made no difference to laboratory organisation in their opinion and, indeed, the laboratory organisation was not altered.

Table (8.4): *Question (2): Students' opinions about first experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
With Pre-lab	45	69	24	7	32.1	3	< 0.001
Without Pre-lab	50	32	10	58			
Q2 (b)	*Is this experiment helpful*						
With Pre-lab	45	64	31	5	22.1	2	< 0.001
Without Pre-lab	50	42	20	38			
Q2 (c)	*Is this experiment meaningful*						
With Pre-lab	45	47	40	13	6.8	2	< 0.05
Without Pre-lab	50	34	40	26			
Q2 (d)	*Is this experiment understandable*						
With Pre-lab	45	62	18	20	11.5	2	< 0.01
Without Pre-lab	50	38	24	38			
Q2 (e)	*Is this experiment satisfying*						
With Pre-lab	45	48	22	30	11.2	5	< 0.05
Without Pre-lab	50	28	26	46			
Q2 (f)	*Is this experiment interesting*						
With Pre-lab	45	69	15	16	9.8	4	< 0.05
Without Pre-lab	50	38	34	28			
Q2 (g)	*Is this experiment well-organised*						
With Pre-lab	45	31	58	11	4.6	5	ns
Without Pre-lab	50	28	34	38			

However, even with the '*with pre-laboratory group*', there is still some doubt about the meaningfulness of the experiment and this might relate to doubts that they find it satisfying. In addition, they are very unsure if the experiment is well-organised.

Overall, in the questions asked, there is a consistent pattern that the "*with pre-laboratory group*' is more positive than then '*without pre-laboratory exercise group*'. This is encouraging but performance in the post-laboratory exercise is, perhaps, more important.

8.2.2 Comparison of the Scores for First Experiment

Table (8.5): *Patterns of scores of the students in laboratory marks, by group*

Group	***Scores***					
	4/10	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
With Pre-lab	0%	4%	18%	27%	38%	13%
Without Pre-lab	8%	16%	34%	24%	18%	0%

Table (8.6): *t-test for laboratory marks, by group*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
With Pre-lab	45	7.3	1.1	4.20	p<0.01
Without Pre-lab	50	6.2	1.5		

The t-test result shows that the '*with pre-laboratory group*' outperform the '*without pre-laboratory group*' quite markedly. This result indicates that the pre-labs were helping understanding.

Having looked at the overall, gender is now considered.

8.2.3 Males and Females of Experimental Group in Experiment 1

As before, Tables 8.7 and 8.8 include only the positive version of the questions which are referred by (a, b, d, k, l, m, n, p, q, and r).

Table (8.7): *Question (1): Gender opinions about first experiment (a, b, d, k, l)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Male	25	84	0	16	6.0	1	< 0.05
Female	20	50	0	50			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
Male	25	84	0	16	3.3	1	ns
Female	20	60	0	40			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
Male	25	84	0	16	7.6	1	< 0.01
Female	20	45	30	25			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
Male	25	84	0	16	6.0	1	< 0.05
Female	20	50	10	40			
Q1 (l)	*It was easy to follow the laboratory manual*						
Male	25	84	0	16	6.0	1	< 0.05
Female	20	50	0	50			

Males seem more positive than females, with five items showing differences that are significant.

Table (8.8): *Question (1): Gender opinions about first experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
Male	25	88	0	12	6.2	1	< 0.05
Female	20	55	5	40			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
Male	25	84	0	16	2.2	1	ns
Female	20	65	0	35			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
Male	25	84	4	12	6.0	1	< 0.05
Female	20	50	10	40			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Male	25	52	24	24	0.2	1	ns
Female	20	45	40	15			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Male	25	84	0	16	7.6	1	< 0.01
Female	20	45	25	30			

Again, the men are more positive in three of the five items.

Table (8.9): *Question (2): Gender opinions about first experiment (a, b, c, d, e, f, g)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
Male	25	84	16	0	7.3	2	< 0.05
Female	20	50	35	15			
Q2 (b)	*Is this experiment helpful*						
Male	25	76	24	0	5.0	2	ns
Female	20	50	40	10			
Q2 (c)	*Is this experiment meaningful*						
Male	25	64	28	8	6.8	2	< 0.05
Female	20	25	55	20			
Q2 (d)	*Is this experiment understandable*						
Male	25	76	20	4	9.1	2	< 0.05
Female	20	45	15	40			
Q2 (e)	*Is this experiment satisfying*						
Male	25	60	20	20	3.1	2	ns
Female	20	35	25	35			
Q2 (f)	*Is this experiment interesting*						
Male	25	84	4	12	6.0	2	< 0.05
Female	20	50	30	20			
Q2 (g)	*Is this experiment well-organised*						
Male	25	44	52	4	5.9	2	< 0.05
Female	20	15	65	20			

A similar pattern is seen here, with men tending to be more positive.

8.2.4 Gender with Pre-laboratory Exercise Group

Table (8.10): *Patterns of scores of the students in laboratory marks, by gender*

	Scores				
Group	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
Male	12%	12%	24%	40%	12%
Female	0%	25%	25%	35%	15%

Table (8.11): *t-test for laboratory marks, by gender*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
Male	25	7.3	1.21	0.35	ns
Female	20	7.4	1.25		

It is interesting to note that, although the men considered that they had gained much more benefit than the women had indicated, both men and women performed equally well, on average.

8.3 Second Experiment

8.3.1 Students Opinions about Second Experiment

As before, Tables 8.12 and 8.13 include only the positive version of the question which are referred by (a, b, d, k, l, m, n, p, q, r).

Table (8.12): *Question (1): Students' opinions about second experiment (a, b, d, k, l)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
With Pre-lab	45	71	0	29	23.9	2	< 0.001
Without Pre-lab	50	38	0	62			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
With Pre-lab	45	71	4	25	31.9	2	<0.001
Without Pre-lab	50	32	10	58			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
With Pre-lab	45	69	0	31	50.6	2	< 0.001
Without Pre-lab	50	24	14	62			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
With Pre-lab	45	73	9	18	40.4	2	<0.001
Without Pre-lab	50	30	16	54			
Q1 (l)	*It was easy to follow the laboratory manual*						
With Pre-lab	45	47	20	33	15.8	4	< 0.01
Without Pre-lab	50	28	22	50			

From Table 8.12, it can be seen that there are very marked differences between the two groups, with the students in '*with pre-laboratory group*' expressed much more positive opinions than those in the '*without pre-laboratory exercise group*'. However, even with the '*with pre-laboratory group*', the lab manual is not yet regarded highly.

Table (8.13): *Question (1): Students' opinions about second experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
With Pre-lab	45	71	0	29	41.5	4	< 0.001
Without Pre-lab	50	28	10	62			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
With Pre-lab	45	71	0	29	52.5	2	<0.001
Without Pre-lab	50	38	0	62			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
With Pre-lab	45	69	0	31	28.2	2	<0.001
Without Pre-lab	50	42	0	58			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
With Pre-lab	45	67	22	11	28.9	2	<0.001
Without Pre-lab	50	30	34	36			
Q1 (r)	*The experiment helped me to understand some of the course work*						
With Pre-lab	45	71	7	22	75.3	2	< 0.001
Without Pre-lab	50	20	20	60			

Again, the students from '*with pre-laboratory group*' are very much more positive than students from '*without pre-laboratory exercise group*' regarding to easiness of using apparatus, completing of this experiment within the prescribed time, clarity of experimental procedure, their ability to use their knowledge in other contexts, and finally their understanding to some of the course work after this experiment.

The pattern in the table below is also consistent with that in the two previous tables, with the students from '*with pre-laboratory group*' seeing this experiment as much more useful, helpful, and also understandable, meaningful, satisfying, interesting. However, the '*with pre-laboratory group*' are less happy with the organisation and, indeed, are still not fully convinced that the experiment is meaningful, satisfying or interesting

Table (8.14): *Question (2): Students' opinions about second experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
With Pre-lab	45	75	16	9	21.2	2	<0.001
Without Pre-lab	50	46	30	24			
Q2 (b)	*Is this experiment helpful*						
With Pre-lab	45	73	16	11	31.2	2	< 0.001
Without Pre-lab	50	34	32	34			
Q2 (c)	*Is this experiment meaningful*						
With Pre-lab	45	56	31	13	24.3	3	< 0.001
Without Pre-lab	50	34	32	34			
Q2 (d)	*Is this experiment understandable*						
With Pre-lab	45	69	13	18	43.3	2	< 0.001
Without Pre-lab	50	26	24	50			
Q2 (e)	*Is this experiment satisfying*						
With Pre-lab	45	38	49	13	32.6	3	<0.001
Without Pre-lab	50	32	30	38			
Q2 (f)	*Is this experiment interesting*						
With Pre-lab	45	49	31	20	17.2	4	< 0.01
Without Pre-lab	50	36	32	32			
Q2 (g)	*Is this experiment well-organised*						
With Pre-lab	45	24	60	16	54.1	3	<0.001
Without Pre-lab	50	46	20	34			

8.3.2 Comparison of the Scores For Second Experiment

Table (8.15): *Patterns of scores of the students in laboratory marks, by group*

Group	***Scores***					
	4/10	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
With Pre-lab	0%	15%	27%	31%	18%	9%
Without Pre-lab	0%	12%	34%	28%	22%	4%

Table (8.16): *t-test for laboratory marks, by group*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
With Pre-lab	45	7.2	1.2	1.7	ns
Without Pre-lab	50	6.8	1.2		

From the Table 8.15 and 8.16, the comparison between performances of students in both groups in the post laboratory exercise is statistically not significant.

Having looked at the overall, gender is now considered.

8.3.3 Males and Females of Experimental Group in Experiment 2

As before, Tables 8.17 and 8.18 include only the positive version of the question.

Table (8.17): *Question (1): Gender opinions about second experiment (a, b, d, k, l)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Male	25	68	0	32	0.3	1	ns
Female	20	75	0	25			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
Male	25	68	4	28	0.4	2	ns
Female	20	75	5	20			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
Male	25	64	0	36	4.5	2	ns
Female	20	75	0	25			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
Male	25	68	8	24	1.5	2	ns
Female	20	80	10	10			
Q1 (l)	*It was easy to follow the laboratory manual*						
Male	25	40	20	40	1.7	3	ns
Female	20	55	20	25			

Males and females show similar views.

Table (8.18): *Question (1): Gender opinions about second experiment (m, n, p, q, r)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
Male	25	68	0	32	0.3	1	ns
Female	20	75	0	25			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
Male	25	68	0	32	0.3	1	ns
Female	20	76	0	25			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
Male	25	64	0	36	0.6	1	ns
Female	20	75	0	25			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Male	25	64	20	16	0.2	1	ns
Female	20	70	25	5			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Male	25	64	8	28	1.4	2	ns
Female	20	80	5	15			

Table (8.19): *Question (2): Gender opinions about second experiment (a, b, c, d, e, f, g)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
Male	25	72	20	8	1.3	2	ns
Female	20	80	10	10			
Q2 (b)	*Is this experiment helpful*						
Male	25	72	24	4	0.1	1	ns
Female	20	75	5	20			
Q2 (c)	*Is this experiment meaningful*						
Male	25	56	32	12	0.1	2	ns
Female	20	55	30	15			
Q2 (d)	*Is this experiment understandable*						
Male	25	68	20	12	2.9	2	ns
Female	20	70	5	25			
Q2 (e)	*Is this experiment satisfying*						
Male	25	48	32	20	2.5	1	ns
Female	20	25	70	5			
Q2 (f)	*Is this experiment interesting*						
Male	25	52	20	28	4.1	2	ns
Female	20	45	45	10			
Q2 (g)	*Is this experiment well-organised*						
Male	25	36	48	16	4.5	2	ns
Female	20	10	75	15			

Again, males and females show similar views in the above two tables.

8.3.4 Gender with Pre-Laboratory Exercise Group

Table (8.20): *Patterns of scores of the students in laboratory marks, by gender*

	Scores				
Group	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
Male	12%	12%	36%	20%	20%
Female	5%	25%	25%	35%	10%

Table (8.21): *t-test for laboratory marks, by gender*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
Male	25	7.2	1.27	0.10	ns
Female	20	7.2	1.11		

There is no difference between male and female in the performance in the post laboratory exercise. Thus, in most items the men and women think similarly and they perform equally well.

8.4 Third experiment

8.4.1 Students Opinion about Third Experiment

As before, Tables 8.22 and 8.23 include only the positive version of the question which are referred by (a, b, d, k, l, m, n, p, q, and r).

In this experiment as seen in Table 8.22, the students in the '*with pre-laboratory group*' saw the experiment as easier, the purpose being clearer for them when they started the experiment, topic becoming more interesting after having done this experiment, the preparation for this experiment was enough, and easier to follow the laboratory manual.

Table (8.22): *Question (1): Students' opinions about third experiment (a, b, d, k, l)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
With Pre-lab	45	62	0	38	4.8	1	< 0.05
Without Pre-lab	50	46	0	54			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
With Pre-lab	45	73	7	20	15.7	2	< 0.001
Without Pre-lab	50	44	2	54			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
With Pre-lab	45	67	9	24	21.5	2	< 0.001
Without Pre-lab	50	34	10	56			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
With Pre-lab	45	62	9	29	30.2	2	< 0.001
Without Pre-lab	50	26	16	58			
Q1 (l)	*It was easy to follow the laboratory manual*						
With Pre-lab	45	64	7	29	9.3	2	< 0.01
Without Pre-lab	50	42	8	50			

Hence, '*with pre-laboratory group*' are more positive than the '*without pre-laboratory exercise group*'.

Table (8.23): *Question (1): Students' opinions about third experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
With Pre-lab	45	60	7	33	5.8	2	< 0.05
Without Pre-lab	50	46	4	50			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
With Pre-lab	45	78	0	22	10.4	2	< 0.01
Without Pre-lab	50	56	0	44			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
With Pre-lab	45	64	20	16	23.3	3	< 0.001
Without Pre-lab	50	38	16	46			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
With Pre-lab	45	60	20	20	14.0	4	< 0.01
Without Pre-lab	50	34	30	36			
Q1 (r)	*The experiment helped me to understand some of the course work*						
With Pre-lab	45	62	11	27	20.1	3	< 0 .001
Without Pre-lab	50	28	10	62			

The '*pre-laboratory exercise group*' have positive opinions about these issues: easy to use the apparatus, experimental procedure was much clearer due to preparation, applying the knowledge in other contexts after having done this experiment, the experiment helped them to understand some of the course work.

Table (8.24): *Question (2): Students' opinions about third experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
With Pre-lab	45	65	22	13	3.0	3	ns
Without Pre-lab	50	56	22	22			
Q2 (b)	*Is this experiment helpful*						
With Pre-lab	45	65	11	24	1.2	4	ns
Without Pre-lab	50	58	12	30			
Q2 (c)	*Is this experiment meaningful*						
With Pre-lab	45	49	33	18	1.8	4	ns
Without Pre-lab	50	42	34	24			
Q2 (d)	*Is this experiment understandable*						
With Pre-lab	45	71	16	13	1.6	2	ns
Without Pre-lab	50	62	20	18			
Q2 (e)	*Is this experiment satisfying*						
With Pre-lab	45	57	24	18	2.1	4	ns
Without Pre-lab	50	48	26	26			
Q2 (f)	*Is this experiment interesting*						
With Pre-lab	45	44	40	16	2.9	4	ns
Without Pre-lab	50	42	32	26			
Q2 (g)	*Is this experiment well-organised*						
With Pre-lab	45	36	53	11	1.5	3	ns
Without Pre-lab	50	32	50	18			

From Table 8.24, it can be seen that there are no significant differences between the two groups. This suggests that the pre-laboratory exercise did not have any great impact in this experiment. Indeed, overall the experiment is not rated too highly in regard to it being interesting and the organisation is questioned. In addition, chi-square calculations have been calculated based on the original six point scales. It is critical in undertaking chi-square calculations that no category falls below five Delucchi, (1983). These data were grouped as necessary and the degrees of freedom fell concomitantly. The approach is outlined in Appendix F. A program, specifically designed for the purpose, was used to carry out the calculations.

8.4.2 Comparison of the Scores for Third Experiment

Table (8.25): *Patterns of scores of the students in laboratory marks, by group*

Group	***Scores***					
	4/10	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
With Pre-lab	0%	0%	0%	35%	38%	27%
Without Pre-lab	0%	13%	12%	12%	8%	5%

Table (8.26): *t-test for laboratory marks, by group*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
With Pre-lab	45	7.9	0.79	4.6	$p<0.001$
Without Pre-lab	50	6.9	1.3		

From Tables 8.25 and 8.26 '*with pre-laboratory group*' achieved higher scores than '*without pre-laboratory exercise group*'. Indeed, the difference is marked, with no one from '*with pre-laboratory group*' achieving scores of five or six, while many students from '*without pre-laboratory exercise group*' achieved these scores.

Having looked at the overall, gender is now considered.

8.4.3 Males and Females of Experimental Group in Experiment 3

As before, Tables 8.27 and 8.28 include only the positive version of the questions which are referred by (a, b, d, k, l, m, n, p, q, and r).

Table (8.27): *Question (1): Gender opinions about third experiment (a, b, d, k, l)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Male	25	56	0	44	0.9	1	ns
Female	20	70	0	30			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
Male	25	72	12	16	0.1	1	ns
Female	20	75	0	25			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
Male	25	60	12	28	1.1	2	ns
Female	20	75	5	20			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
Male	25	60	12	28	0.1	1	ns
Female	20	65	5	30			
Q1 (l)	*It was easy to follow the laboratory manual*						
Male	25	60	8	32	0.5	2	ns
Female	20	70	5	25			

Table (8.28): *Question (1): Gender opinions about third experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
Male	25	56	4	40	1.5	2	ns
Female	20	65	10	25			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
Male	25	76	0	24	0.1	1	ns
Female	20	80	0	20			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
Male	25	60	24	16	0.5	1	ns
Female	20	70	15	15			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Male	25	48	32	20	3.4	1	ns
Female	20	75	5	20			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Male	25	60	12	28	0.2	4	ns
Female	20	65	10	25			

There are no gender differences in their views for Table 8.27 and 8.28

Table (8.29): *Question (2): Gender opinions about third experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
Male	25	64	24	12	0.2	2	ns
Female	20	65	20	15			
Q2 (b)	*Is this experiment helpful*						
Male	25	52	32	16	3.8	2	ns
Female	20	80	15	5			
Q2 (c)	*Is this experiment meaningful*						
Male	25	40	36	24	2.3	2	ns
Female	20	60	30	10			
Q2 (d)	*Is this experiment understandable*						
Male	25	72	12	16	0.8	2	ns
Female	20	70	20	10			
Q2 (e)	*Is this experiment satisfying*						
Male	25	52	32	16	1.7	2	ns
Female	20	65	15	20			
Q2 (f)	*Is this experiment interesting*						
Male	25	40	48	12	1.6	2	ns
Female	20	50	30	20			
Q2 (g)	*Is this experiment well-organised*						
Male	25	28	68	4	5.7	2	ns
Female	20	45	35	20			

Again, no gender differences are observed.

8.4.4 Gender with Pre-laboratory Exercise Group

Table (8.30): *Patterns of scores of the students in laboratory marks, by gender*

	Scores				
Group	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
Male	0%	0%	40%	36%	24%
Female	0%	0%	30%	40%	30%

Table (8.31): *t-test for laboratory marks, by gender*

Group	N	Mean	S. D.	t value	Significance
Male	25	7.8	0.80	0.67	ns
Female	20	8.0	0.79		

Based on gender, there are no statistically significant differences in performance in the post-laboratory test.

8.5 Fourth experiment

8.5.1 Students Opinions about Fourth Experiment

As before, Tables 8.32 and 8.33 include only the positive version of the question which are referred by (a, b, d, k, l, m, n, p, q, and r).

Table (8.32): *Question (1): Students' opinions about four experiment (a, b, d, k, l)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
With Pre-lab	50	66	0	34	5.6	2	< 0.05
Without Pre-lab	45	51	0	49			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
With Pre-lab	50	70	8	22	11.1	2	< 0.01
Without Pre-lab	45	46	7	47			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
With Pre-lab	50	62	8	30	9.1	2	< 0.05
Without Pre-lab	45	42	5	53			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
With Pre-lab	50	66	12	22	14.9	3	< 0.001
Without Pre-lab	45	42	11	47			
Q1 (l)	*It was easy to follow the laboratory manual*						
With Pre-lab	50	64	4	32	9.3	2	< 0.01
Without Pre-lab	45	45	2	53			

Students in '*with pre-laboratory group*' are more positive than '*without pre-laboratory exercise'* group in every item in the Table 8.32 although the differences are not as marked as in some of the other experiments.

Table (8.33): *Question (1): Students' opinions about fourth experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
With Pre-lab	50	68	2	30	16.5	2	< 0.001
Without Pre-lab	45	40	2	58			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
With Pre-lab	50	70	0	30	40.2	2	< 0.001
Without Pre-lab	45	44	0	56			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
With Pre-lab	50	70	14	16	32.8	3	< 0.001
Without Pre-lab	45	37	16	47			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
With Pre-lab	50	16	28	56	3.1	3	ns
Without Pre-lab	45	22	20	58			
Q1 (r)	*The experiment helped me to understand some of the course work*						
With Pre-lab	50	60	24	16	29.7	3	< 0.001
Without Pre-lab	45	38	15	47			

Table (8.34): *Question (2): Students' opinions about fourth experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
With Pre-lab	50	74	18	8	12.7	2	< 0.01
Without Pre-lab	45	49	24	27			
Q2 (b)	*Is this experiment helpful*						
With Pre-lab	50	72	16	12	11.2	4	< 0.05
Without Pre-lab	45	53	22	25			
Q2 (c)	*Is this experiment meaningful*						
With Pre-lab	50	50	28	22	4.6	2	ns
Without Pre-lab	45	38	27	35			
Q2 (d)	*Is this experiment understandable*						
With Pre-lab	50	76	6	18	13.4	2	< 0.01
Without Pre-lab	45	51	25	24			
Q2 (e)	*Is this experiment satisfying*						
With Pre-lab	50	38	48	14	30.2	3	< 0.001
Without Pre-lab	45	38	26	36			
Q2 (f)	*Is this experiment interesting*						
With Pre-lab	50	40	52	8	5.0	2	ns
Without Pre-lab	45	44	31	25			
Q2 (g)	*Is this experiment well-organised*						
With Pre-lab	50	34	52	14	8.2	3	< 0.05
Without Pre-lab	45	42	36	22			

Table 8.33 reveals that '*with pre-laboratory group*' are markedly more positive than the '*without pre-laboratory exercise group*' in four of the five items. However, neither group are able to see how they can apply the knowledge in other contexts.

In many items in Table 8.34, the differences are small or not statistically significant. For both groups, the experiment is not seen as meaningful or interesting for a high proportion of the students. Indeed, while the view of satisfaction has risen for the '*with pre-laboratory group*', it is still not high. As with previous experiments the level of organisation is somewhat unsatisfactory.

8.5.2 Comparison of the Scores for Fourth Experiment.

Table (8.35): *Patterns of scores of the students in laboratory marks, by group*

Group	***Scores***					
	4/10	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
With Pre-lab	0%	0%	0%	34%	34%	32%
Without Pre-lab	0%	13%	20%	31%	20%	16%

Table (8.36): *t-test for laboratory marks, by group*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
With Pre-lab	50	8.0	0.82	4.2	p<0.01
Without Pre-lab	45	7.0	1.26		

It could be seen in Table 8.35 and 8.36 that students in '*with pre-laboratory group*' achieved markedly higher scores in the post laboratory exercise more than students in '*without pre-laboratory exercise groups*'.

Having looked at the overall, gender is now considered.

8.5.3 Male and Female of Experimental Group in Experiment 4

As before, Tables 8.37 and 8.38 include only the positive version of the questions which are referred by (a, b, d, k, l, m, n, p, q, and r).

It can be seen from Table 8.37 that there are no significant differences in response patterns relating to gender.

On the other hand, the only gender difference in Table 8.38 relates to apply knowledge in other contexts where the women are more positive than the men.

Table (8.37): *Question (1): Gender opinions about four experiment (a, b, d, k, l)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Male	20	75	0	25	1.2	1	ns
Female	30	60	0	40			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
Male	20	80	5	15	1.6	1	ns
Female	30	63	10	27			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
Male	20	75	5	20	2.4	1	ns
Female	30	53	10	37			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
Male	20	75	10	15	1.3	2	ns
Female	30	60	13	27			
Q1 (l)	*It was easy to follow the laboratory manual*						
Male	20	70	0	30	0.5	1	ns
Female	30	60	7	33			

Table (8.38): *Question (1): Gender opinions about fourth experiment (m, n, p, q, r)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
Male	20	80	0	20	2.5	2	ns
Female	30	60	3	37			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
Male	20	75	0	25	0.4	1	ns
Female	30	67	0	33			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
Male	20	75	20	5	0.4	1	ns
Female	30	67	10	23			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Male	20	15	10	75	6.0	2	< 0.05
Female	30	17	40	43			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Male	20	65	25	10	0.3	1	ns
Female	30	57	23	20			

Table (8.39): *Question (2): Gender opinions about fourth experiment (a, b, c, d, e, f, g)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
Male	20	70	15	15	2.3	2	ns
Female	30	77	20	3			
Q2 (b)	*Is this experiment helpful*						
Male	20	80	10	10	1.2	2	ns
Female	30	67	20	13			
Q2 (c)	*Is this experiment meaningful*						
Male	20	60	30	10	2.9	2	ns
Female	30	43	27	30			
Q2 (d)	*Is this experiment understandable*						
Male	20	80	5	15	0.3	2	ns
Female	30	73	7	20			
Q2 (e)	*Is this experiment satisfying*						
Male	20	35	50	15	0.1	2	ns
Female	30	40	47	13			
Q2 (f)	*Is this experiment interesting*						
Male	20	35	55	10	0.4	2	ns
Female	30	43	50	7			
Q2 (g)	*Is this experiment well-organised*						
Male	25	35	55	10	0.5	2	ns
Female	20	33	50	17			

There are no gender differences here.

8.5.4 Gender with Pre-laboratory Exercise Group

Table (8.40): *Patterns of scores of the students in laboratory marks, by gender*

	Scores				
Group	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
Male	0%	0%	25%	40%	35%
Female	0%	0%	40%	30%	30%

Table (8.41): *t-test for laboratory marks, by gender*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
Male	20	8.1	0.79	0.84	ns
Female	30	7.9	0.84		

There are no gender differences.

8.6 Fifth experiment

8.6.1 Students Opinion about Fifth Experiment

As before, Tables 8.42 and 8.43 include only the positive version of the question which are referred by (a, b, d, k, l, m, n, p, q, and r).

It could be seen in the Table 8.42 that '*with pre-laboratory group*' are very much more positive in all aspects included in the table. The effect of the pre-lab on the interest in the experiment, the understanding, and the accessibility of the laboratory manual is remarkable.

Table (8.42): *Question (1): Students' opinions about fifth experiment (a, b, d, k, l)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
With Pre-lab	50	76	0	24	20.4	2	< 0.001
Without Pre-lab	45	44	0	56			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
With Pre-lab	50	76	0	24	27.7	2	< 0.001
Without Pre-lab	45	40	7	53			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
With Pre-lab	50	78	6	16	73.2	2	< 0.001
Without Pre-lab	45	33	11	56			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
With Pre-lab	50	76	2	22	54.1	2	< 0.001
Without Pre-lab	45	29	9	62			
Q1 (l)	*It was easy to follow the laboratory manual*						
With Pre-lab	50	76	2	22	55.7	2	< 0.001
Without Pre-lab	45	29	7	64			

In addition, in every area in Table 8.43 below, the '*with pre-laboratory group*' is much more positive. In particular, the clarity of the experimental procedure has been greatly enhanced.

Table (8.43): *Question (1): Students' opinions about fifth experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
With Pre-lab	50	74	0	26	33.1	2	< 0.001
Without Pre-lab	45	36	9	55			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
With Pre-lab	50	76	0	24	30.0	2	< 0.001
Without Pre-lab	45	40	0	60			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
With Pre-lab	50	72	10	18	65.1	3	< 0.001
Without Pre-lab	45	27	11	62			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
With Pre-lab	50	56	22	22	25.2	4	< 0.001
Without Pre-lab	45	29	29	42			
Q1 (r)	*The experiment helped me to understand some of the course work*						
With Pre-lab	50	58	16	26	30.2	3	< 0.001
Without Pre-lab	45	27	16	57			

Table (8.44): *Question (2): Students' opinions about fifth experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
With Pre-lab	50	70	18	12	27.3	2	< 0.001
Without Pre-lab	45	35	25	40			
Q2 (b)	*Is this experiment helpful*						
With Pre-lab	50	68	22	10	29.1	2	< 0.001
Without Pre-lab	45	33	29	38			
Q2 (c)	*Is this experiment meaningful*						
With Pre-lab	50	58	36	6	26.8	3	< 0.001
Without Pre-lab	45	29	42	29			
Q2 (d)	*Is this experiment understandable*						
With Pre-lab	50	68	16	16	28.5	2	< 0.001
Without Pre-lab	45	33	20	47			
Q2 (e)	*Is this experiment satisfying*						
With Pre-lab	50	38	50	12	43.8	3	< 0.001
Without Pre-lab	45	33	25	42			
Q2 (f)	*Is this experiment interesting*						
With Pre-lab	50	52	32	16	5.6	2	ns
Without Pre-lab	45	38	33	29			
Q2 (g)	*Is this experiment well-organised*						
With Pre-lab	50	30	62	8	18.8	2	< 0.001
Without Pre-lab	45	27	42	31			

In most areas, the students in '*with pre-laboratory group*' hold much more positive attitudes. However, the students in both groups do not see the experiment as satisfying while the level of interest is not too high. As with the other experiments, the organisational aspects are not rated highly.

8.6.2 Comparison of the Scores for Fifth Experiment.

Table (8.45): *Patterns of scores of the students in laboratory marks, by group*

Group	***Scores***					
	4/10	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
With Pre-lab	0%	0%	0%	26%	42%	32%
Without Pre-lab	0%	13%	22%	38%	22%	18%

Table (8.46): *t-test for laboratory marks, by group*

Group	N	Mean	S. D.	t value	Significance
With Pre-lab	50	8.1	0.77	3.8	$p<0.01$
Without Pre-lab	45	7.4	1.03		

The '*with pre-laboratory group*' outperforms the '*without pre-laboratory group*'

Having looked at the overall, gender is now considered.

8.6.3 Males and Females of Experimental Group in Experiment 5

As before, Tables 8.47 and 8.48 include only the positive version of the questions which are referred by (a, b, d, k, l, m, n, p, q, and r).

Table (8.47): *Question (1): Gender opinions about fifth experiment (a, b, d, k, l)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Male	20	70	0	30	0.7	1	ns
Female	30	80	0	20			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
Male	20	70	0	30	0.7	1	ns
Female	30	80	0	20			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
Male	20	75	5	20	0.2	1	ns
Female	30	80	7	13			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
Male	20	65	5	30	2.2	1	ns
Female	30	83	0	17			
Q1 (l)	*It was easy to follow the laboratory manual*						
Male	20	65	5	30	2.2	1	ns
Female	30	83	0	17			

It is clear from the Table 8.47 that there are no gender differences.

Table (8.48): *Question (1): Gender opinions about fifth experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
Male	20	65	0	35	1.4	1	ns
Female	30	80	0	20			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
Male	20	75	0	25	0.0	1	ns
Female	30	77	0	23			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
Male	20	65	15	20	0.8	1	ns
Female	30	77	7	16			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Male	20	45	30	25	1.8	2	ns
Female	30	63	17	20			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Male	20	50	15	35	1.4	2	ns
Female	30	63	17	20			

Again, there are no gender differences.

Table (8.49): *Question (2): Gender opinions about fifth experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
Male	20	75	20	5	1.6	2	ns
Female	30	67	17	16			
Q2 (b)	*Is this experiment helpful*						
Male	20	65	25	10	0.2	2	ns
Female	30	70	20	10			
Q2 (c)	*Is this experiment meaningful*						
Male	20	55	35	10	1.0	2	ns
Female	30	60	37	3			
Q2 (d)	*Is this experiment understandable*						
Male	20	75	10	15	1.0	2	ns
Female	30	63	20	17			
Q2 (e)	*Is this experiment satisfying*						
Male	20	30	65	5	3.4	2	ns
Female	30	43	40	17			
Q2 (f)	*Is this experiment interesting*						
Male	20	40	50	10	5.1	2	< 0.01
Female	30	60	20	20			
Q2 (g)	*Is this experiment well-organised*						
Male	20	30	65	5	0.4	2	ns
Female	30	30	60	10			

There are no gender differences except that the women find the experiment more interesting.

8.6.4 Gender with Pre-Laboratory Exercise Group

Table (8.50): *Patterns of scores of the students in laboratory marks, by gender*

	Scores				
Group	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
Male	0%	0%	35%	35%	30%
Female	0%	0%	20%	46%	34%

Table (8.51): *t-test for laboratory marks, by gender*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
Male	20	8.0	0.83	0.83	ns
Female	30	8.1	0.73		

Men and women performed equally well.

8.7 Discussion

In looking at all five experiments, it is clear that the '*with pre-laboratory group*' are remarkably and consistently more positive in their views when compared to the '*without pre-laboratory group.*' They are clearly making more sense of the entire laboratory experience, while finding it much more enjoyable, interesting and satisfying. Of even greater importance, they are performing better in the post-laboratory exercises, suggesting that they understand better. They are also finding the lab work helping them more in relation to course work. Johnstone and Al-Shuaili (2001) pinpoint some key goals for lab work and they lay stress on the importance of the affective. Clearly, the pre-laboratory experiences here are enhancing affective outcomes most positively.

As might be expected, there are some specific differences between the various experiments. The most positive interest came with the experiment involving x-rays while the determination of the wavelength of sodium light by using Newton's Rings was least attractive. In general, the students were positive about the laboratory manual although this varied somewhat from experiment to experiment. However, they have no other manual with which to compare it. The preparation and presentation of the manual is critical as Carnduff and Reid (2003) note, there needing to be clear aims for each experiment, appropriate background, as well as procedures outlined in clear ways.

Johnstone and Al-Shuaili (2001) stated that, "*it is not enough to tell students to observe, they have to show how.*" Responses from the '*with pre-laboratory group*' relating to the experimental procedures are remarkably and consistently more positive in their views when compared to the '*without pre-laboratory group*'

Kirschner and Meester (1988) suggested that, "*using knowledge and skills in unfamiliar situation*" is one of the general objectives for practical work. Here the outcomes are not so positive although the '*with pre-laboratory group'* held good views for the experiments on the determination of the wavelength of sodium light by using Newton's Rings, and the determination of wavelength of light from the helium neon laser by using diffraction grating.

Shymansky and Penick (1979) and Black and Ogborn (1979) grouped aims of practical work into four classifications. One of them involved the idea that the lab work could illustrate ideas, thus helping students to understand course-work better. This also seem to have been achieved.

In terms of the meaningfulness of the experimental work, two experiments (determination of the refraction index of a glass prism using a spectrometer, determination of wavelength of light from the helium neon laser by using diffraction grating) did not show as positive outcomes as the other three with the '*with pre-laboratory group.*' This may simply reflect the subject matter.

One key finding is that the '*with pre-laboratory group*' felt that the experiments were much more understandable compared to the '*without pre-laboratory group*'. This almost certainly reflects the reduction in working memory overload, allowing more cognitive capacity to make sense of what they were doing. Indeed, the development of the pre-lab idea by Johnstone was based primarily on the need to take account of limited working memory capacity (Johnstone *et al.*, 1994).

The post-laboratory exercises were introduced at the end of each experiment to give a student opportunity to review their work and to apply the ideas gained. The aim is to link the ideas learnt in the actual laboratory to ideas previously learnt. This may lead to richer connections between ideas held in long-term memory. The post-laboratory exercises were designed to apply ideas and the markedly better performance of the '*with pre-laboratory group*' is very strong evidence that the pre-laboratory exercise were having the desired affect.

It often said that Physics is for males not for females. The result from this stage tells another story. The men are more positive in some experiments, the women in others. This is consistent with the findings of Skryabina who saw both genders equally interested in Physics but interested in different areas (Reid & Skryabina, 2002). However, the performance in the post-laboratory exercises reveals how men and women can perform equally well, overall.

In conclusion, it is clear that the pre-laboratory exercises had a great effect on the students' opinions and feelings as well as their learning. The pre-lab prepares the mind for what is lying ahead when the experiment is undertaken. This reduces cognitive load and allows more capacity for thought, thus generating more positive attitudes. However, it has to be noted that, "*knowing what to observe, knowing how* *to observe it, observing it and describing the observation are all theory-dependent and therefore fallible and biased.*"(Hodson, 1986). Care was taken in designing the pre-labs to minimise this problem.

Kempa and Ward (1988) reported that observationality is depending on two factors: the nature and intensity of a stimulus and also on the observer's perceptual characteristics. For the first factor, observational stimulus must reach a certain level below which observation will not be made (observation threshold). In that context, Young (1979) differentiated between '*seeing*' and '*observing*', noting that the learner may '*see*' many things, but they do not always '*observe*' them. Kempa and Ward (1988) reported that students failed to notice or record one in every three observations.

8.8 Main Conclusions

The key findings are now summarised. Table 8.52, provided at the end of the chapter, also summarises the results.

(1) In almost all the survey items, the responses of the '*with pre-laboratory group*' were significantly more positive than the responses from the '*without pre-laboratory group*' (only 12 out of 85 showed no significant difference).

(2) The differences in responses to survey items varied from experiment to experiment, with experiment 2 showing the most frequent statistical differences (and mostly at 0.1%).

(3) Even using the pre-laboratory exercises did not improve the perceived ability to apply the ideas learnt to a satisfactory level.

(4) The laboratory organisation received a consistently poor rating.

(5) In four experiments, the improved performance of the '*with pre-laboratory group*' in the post-laboratory exercises was highly significant.

(6) In five experiments, the improved performance of the '*with pre-laboratory group*' in the post-laboratory exercises showed no difference with gender.

(7) In almost no survey items in experiments 2 to 5 were there differences in response patterns with gender (5 of 68). In experiment one, 12 of the 17 items showed differences where the males were more positive.

After investigating the effect of pre-laboratory exercises on student perceptions of their university physics experiments, and their performance in a post-lab test, the next chapter will discuss the third stage of this study. In this, pre-laboratory exercises were used again but the lab manual was re-cast to simplify it and make it more consistent with the pre-lab exercises. The aim here was to reduce the amount of extraneous 'noise' in the manual, allowing the students to focus better on the task in hand. In addition, the post-lab exercises were extended considerably to make the whole learning experience (pre-laboratory exercise, laboratory manual and post-lab exercises) a more cohesive whole.

In addition, at the end of stage three, semi-structured interviews were carried out with universities teachers to explore the views of university teachers related to physics laboratories in Libya.

Table (8.52): *Summary of chapter 8 results*

	Statements with significant differences	With pre-lab versus Without Pre-lab					Male versus Female - with pre-lab group				
		Experiment					Experiment				
		1	2	3	4	5	1	2	3	4	5
1-a	The experiment was easy to do	Y	Y	Y	Y	Y	Y	N	N	N	N
1-b	The purpose of this experiment was very clear to me when I started the lab work	Y	Y	Y	Y	Y	N	N	N	N	N
1-d	Having done this experiment I now find the topic more interesting	Y	Y	Y	Y	Y	Y	N	N	N	N
1-k	The preparation I did before coming to the laboraotry was enough, and helped me to undertsand what I was doing.	Y	Y	Y	Y	Y	Y	N	N	N	N
1-l	It was easy to follow the laboratory manual	Y	Y	Y	Y	Y	Y	N	N	N	N
1-m	For this experiment it was east to use the apparatus	Y	Y	Y	Y	Y	Y	N	N	N	N
1-n	I successfully completed this experiment within the prescribed time	Y	Y	Y	Y	Y	N	N	N	N	N
1-p	Experimental procedure was more clear due to my preparation	Y	Y	Y	Y	Y	Y	N	N	N	N
1-q	Having done this experiment, I can see how to apply my knowledge in other contexts	Y	Y	Y	N	Y	N	N	N	Y	N
1-r	The experiments helped me to understand some of the course work	Y	Y	Y	Y	Y	Y	N	N	N	N
2-a	Is this experiment useful	Y	Y	N	Y	Y	Y	N	N	N	N
2-b	Is this experiment helpful	Y	Y	N	Y	Y	N	N	N	N	N
2-c	Is this experiment meaningful	Y	Y	N	N	Y	Y	N	N	N	N
2-d	Is this experiment understandable	Y	Y	N	Y	Y	Y	N	N	N	N
2-e	Is this experiment satisfying	Y	Y	N	Y	Y	N	N	N	N	N
2-f	Is this experiment interesting	Y	Y	N	N	N	Y	N	N	N	Y
2-g	Is this experiment well-organised	N	Y	N	Y	Y	Y	N	N	N	N
	Significant performance difference	Y	N	Y	Y	Y	N	N	N	N	N

(Y) for significant, (N) for insignificant.

Chapter 9

Data Analyses (Third stage)

9.1 Introduction

The last chapter has described the effects of introducing pre-laboratory exercises in experimental work in physics in higher education. This was assessed using questionnaires and a post-laboratory test which aimed to assess understanding. The outcomes were very positive.

In the light of these findings, the final stage was planned and carried out, again, in the Physics department at Sebha University

The pre-laboratory exercises were used again, and the full pre-laboratory exercises are in Appendices C.1.1, C.2.1, C.3.1 and C.4.1. However, the post-laboratory exercises were developed considerably (25 minutes for each one after finishing the experiment). Again, the full post-laboratory exercises are in Appendices C.1.3, C.2.3, C.3.3 and C.4.3. Furthermore, the entire set of student instruction sheets was re-written. The aim in doing this was to make the entire laboratory experience a cohesive programme as recommended by Carnduff and Reid (2003). In this way, the pre-laboratory exercises were not an '*add-on*' to an established procedure but the entire laboratory experience was adjusted, the aim being to see if understanding could be enhanced and positive attitudes developed, the full new instruction sheets are in Appendices C.1.2, C.2.2, C.3.2 and C.4.2.

The students were divided randomly into two groups, one group worked without pre-laboratory exercises while the other group worked with pre-laboratory exercises and totally revised experimental instructions. Both groups undertook post-laboratory exercises. A survey was used at the end to assess the student attitudes and the performance in the post-laboratory exercises of the two groups were compared.

Responses to the survey questions from both groups ('*with pre-laboratory group*' and the '*without pre-laboratory group*') will be compared using '*goodness of fit*'chi-square, to see the effect of the pre-laboratory exercise, and re-written instruction sheets on the perceptions of the students, and the students' perspectives regarding the use of pre-laboratory exercise in helping with their success in laboratory. In addition, the performances in the post-laboratory exercises will be compared using a t-test.

In this chapter, the data from the surveys which were used at the end of the selected four experiments will be summarised and discussed. For each question, a table will show the percentages of students selecting each of the responses, as discussed in chapter six.

This chapter also will discuss semi-structured interviews which were carried out with university teachers to explore their views related to physics laboratories in Libya.

Furthermore, comparisons between males and females of '*with pre-laboratory group*' will be discussed in this chapter, both with survey questions and post-laboratory exercises performance, the aim being to explore any differences in perceptions with men and women in relation to the introduction of pre-laboratory exercises. Because the samples are small, chi-square sensitivity will tend to be low.

Four experiments were included in this study and these are summarised in Table 9.1.

Table (9.1): *Title of selected experiment*

	Title	Description
1	Refractive Indices	The determination of the refraction index of a glass prism using a spectrometer.
2	Wavelength of sodium light	Determination of the wavelength of sodium light by using Newton's Rings.
3	Wavelength of light (helium neon laser)	Determination of wavelength of light from the helium neon laser by using diffraction grating.
4	Rotation of the plane of polarisation	Rotation of the plane of polarisation with sugar solutions.

The sample of third stage for this study was also from third year, fifth semester undergraduate students. 106 students contribute in the third stage, some of them worked with pre-laboratory exercise, while the other worked without pre-laboratory exercise, 56 students worked with pre-lab for first two experiments, while 50 worked without pre-lab for these two. Then the these two groups were interchanged, 50 students worked with pre-lab for other two and 56 students worked without pre-lab for these two. There were several reasons in continuing with the optics laboratory in the third stage. It allowed comparisons with the previous findings, showing the effects associated with the changing use of pre-lab and post-lab exercises, as well as the recasting of instruction sheets for all experiments. In each stage, no student had met pre-labs or post-labs before undertaking the optics laboratory course.

Furthermore, ten university teachers were interviewed in this stage as indicated above. The data from each experiment are now discussed in turn. This involves survey questions and the performance in the post-lab exercises. Then, data will be analysed by gender to see if the pre-lab approach is bringing benefits or otherwise equally to men and women.

9.2 First Experiment

9.2.1 Students Opinions about First Experiment

In fact, question one contains twenty items. As before, ten items are phrased positively which are referred by (a, b, d, k, l, m, n, p, q, and r), while the remaining ten are the negative form. This allows consistency of response to be checked. In fact, response patterns never differed by more than 2% in any category and no value of chi-square (as a contingency test) was significant. The original data discussed in Tables 9.2 to 9.47 were derived from data generated on five and six point scales. In the tables, this has been reduced to three categories, simply for clarity. However, all the chi-square calculations have been calculated based on the original five or six point scales. It is critical in undertaking chi-square calculations that no category falls below five (Delucchi, 1949). These data were grouped as necessary and the degrees of freedom fell concomitantly. The approach is outlined in Appendix F.

For simplicity, the Tables 9.2, and 9.3 include only the data for the positive questions.

Table 9.2, shows that the "*with pre-laboratory group*' was very much more positive than the '*without pre-laboratory exercise group*' in every item. Thus, the pre-laboratory experience here made the experiment easier, the purpose clearer, and the lab manual was easier to follow. They saw the preparation in advance as helping them to understand better and the whole topic was made more interesting.

Table (9.2): *Question (1): Students' opinions about first experiment (a, b, d, k, l)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
With Pre-lab	56	70	7	23	32.1	3	< 0.001
Without Pre-lab	50	42	12	46			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
With Pre-lab	56	69	11	20	55.0	3	< 0.001
Without Pre-lab	50	36	8	56			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
With Pre-lab	56	68	9	23	17.6	2	< 0.001
Without Pre-lab	50	24	10	66			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
With Pre-lab	56	68	9	23	34.2	2	< 0.001
Without Pre-lab	50	20	10	70			
Q1 (l)	*It was easy to follow the laboratory manual*						
With Pre-lab	56	70	5	25	13.0	3	< 0.01
Without Pre-lab	50	50	12	38			

Table (9.3): *Question (1): Students' opinions about first experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
With Pre-lab	56	71	9	20	44.3	3	< 0.001
Without Pre-lab	50	24	12	64			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
With Pre-lab	56	75	11	14	10.7	3	< 0.05
Without Pre-lab	50	56	10	34			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
With Pre-lab	56	66	11	23	53.5	3	< 0.001
Without Pre-lab	50	24	10	66			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
With Pre-lab	56	62	11	27	25.6	2	< 0.001
Without Pre-lab	50	22	18	60			
Q1 (r)	*The experiment helped me to understand some of the course work*						
With Pre-lab	56	73	9	18	52.7	3	< 0.001
Without Pre-lab	50	30	10	60			

From Table 9.3, the majority of the '*with pre-laboratory group*' felt that the apparatus was easy to use. Also, they indicated that they had finished the experiment within the described time, and the preparation made the procedure much clearer.In addition, the '*with pre-laboratory group*' are more positive regarding to how to apply their knowledge in other contexts.

Overall, the '*with pre-laboratory group*' is very much more optimistic in every item, even for how to use their knowledge in other contexts.

Table (9.4): *Question (2): Students' opinions about first experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
With Pre-lab	56	61	18	21	10.0	4	< 0.05
Without Pre-lab	50	38	24	38			
Q2 (b)	*Is this experiment helpful*						
With Pre-lab	56	63	16	21	14.3	2	< 0.001
Without Pre-lab	50	38	28	34			
Q2 (c)	*Is this experiment meaningful*						
With Pre-lab	56	62	20	18	8.8	4	ns
Without Pre-lab	50	38	34	28			
Q2 (d)	*Is this experiment understandable*						
With Pre-lab	56	66	16	18	22.0	2	< 0.001
Without Pre-lab	50	36	32	32			
Q2 (e)	*Is this experiment satisfying*						
With Pre-lab	56	61	21	18	25.4	4	< 0.001
Without Pre-lab	50	30	34	36			
Q2 (f)	*Is this experiment interesting*						
With Pre-lab	56	61	20	19	18.3	4	< 0.01
Without Pre-lab	50	36	40	24			
Q2 (g)	*Is this experiment well-organised*						
With Pre-lab	56	59	18	23	45.3	4	< 0.001
Without Pre-lab	50	28	28	44			

From Table 9.4, the '*with pre-laboratory group*' was very markedly more positive than the '*without pre-laboratory exercise group*' in seeing the experiment as useful, helpful, and meaningful. They were also more positive, seeing the experiment as understandable, satisfying, and interesting. In addition, the '*with pre-laboratory exercise group*' felt more positive regarding to laboratory organisation than the other group.

The aim of the question in Table 9.5 below is to investigate how students interact in the laboratory with their colleagues. In presenting the data, the percentage in the '*positive*' category refers to those who were actually positive. For example, under the first question ('*I found the discussion boring*'), 59% and 62% are shown as positive: these are the responses, for the two groups, where the respondents *disagreed* with the statement.

Table (9.5): *Question (3): Students' opinions about first experiment (a, b, c, d, e, f)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q3 (a)	*I found discussions boring.*						
With Pre-lab	56	59	12	29	5.0	2	ns
Without Pre-lab	50	62	0	38			
Q3 (b)	*I enjoyed working with members of my group.*						
With Pre-lab	56	59	12	29	2.2	4	ns
Without Pre-lab	50	64	10	26			
Q3 (c)	*Most of the ideas were not helpful.*						
With Pre-lab	56	57	20	23	11.1	4	< 0.05
Without Pre-lab	50	42	10	48			
Q3 (d)	*Most of the ideas came from one person.*						
With Pre-lab	56	57	20	23	4.1	4	ns
Without Pre-lab	50	58	12	30			
Q3 (e)	*Working as a group made it easier for us to get answers.*						
With Pre-lab	56	67	9	23	2.5	4	ns
Without Pre-lab	50	60	14	26			
Q3 (f)	*I did not respect ideas from others since they are always wrong.*						
With Pre-lab	56	66	11	23	1.5	4	ns
Without Pre-lab	50	62	12	26			

While student responses tend to be positive, in only one item is there any significant difference between the groups. In fact, the introduction of pre-labs and revised instructions is unlikely to have any major effect on group dynamics in group discussions. However, it is encouraging that the intervention helped the students to see the helpfulness of the ideas.

9.2.2 Summary

Overall, there is a consistent pattern that the '*with pre-laboratory group*' is more positive than then '*without pre-laboratory exercise group*'. In fact, of the 23 comparison made in the responses patterns between the two groups, 18 of them are significant, all showing the '*with pre-laboratory group*' as more positive. This is encouraging. However, the evidence from the performance in the post-laboratory exercises is more important. This offers evidence of the effectiveness of the pre-laboratory exercises in enhancing understanding.

9.2.3 Comparison of the Scores for First Experiment

Table (9.6): *Patterns of scores of the students in laboratory marks, by group*

Group	*Scores*					
	4/10	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
With Pre-lab	4%	5%	9%	16%	45%	21%
Without Pre-lab	16%	18%	16%	30%	20%	0%

Table (9.7): *t-test for laboratory marks, by group*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
With Pre-lab	56	7.6	1.28	5.28	$p<0.001$
Without Pre-lab	50	6.2	1.39		

From Table 9.6 and 9.7, it is clear that '*with pre-laboratory group*' performed better than students in '*without pre-laboratory exercise group*'.

Having looked at the overall pattern, gender is now considered.

9.2.4 Males and Females of Experimental Group in Experiment 1

As before, Tables 9.8, and 9.9 include only the positive version of the questions which are referred by (a, b, d, k, l, m, n, p, q, and r).

Two items are showing differences that are significant in Table 9.8 while there are no gender differences in Table 9.9.

Table (9.8): *Question (1): Gender opinions about first experiment (a, b, d, k, l)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Male	30	77	13	10	1.1	1	ns
Female	26	62	0	38			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
Male	30	83	3	14	5.7	1	< 0.05
Female	26	54	19	27			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
Male	30	70	7	23	5.0	1	< 0.05
Female	26	58	8	34			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
Male	30	70	7	23	0.1	1	ns
Female	26	65	9	23			
Q1 (l)	*It was easy to follow the laboratory manual*						
Male	30	77	0	23	1.5	1	ns
Female	26	71	12	27			

Table (9.9): *Question (1): Gender opinions about first experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
Male	30	80	7	13	2.3	1	ns
Female	26	61	12	27			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
Male	30	87	3	10	2.3	1	ns
Female	26	62	19	19			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
Male	30	73	10	17	1.5	1	ns
Female	26	58	11	31			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Male	30	60	10	30	0.2	1	ns
Female	26	65	12	23			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Male	30	73	10	17	0.1	1	ns
Female	26	73	8	19			

Again, there are no gender differences in Table 9.10.

Table (9.10): *Question (2): Gender opinions about first experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
Male	30	63	17	20	0.2	2	ns
Female	26	58	19	23			
Q2 (b)	*Is this experiment helpful*						
Male	30	66	17	17	0.9	2	ns
Female	26	58	15	27			
Q2 (c)	*Is this experiment meaningful*						
Male	30	63	17	20	0.4	2	ns
Female	26	62	23	15			
Q2 (d)	*Is this experiment understandable*						
Male	30	57	17	16	0.1	2	ns
Female	26	66	15	19			
Q2 (e)	*Is this experiment satisfying*						
Male	30	57	23	20	0.4	2	ns
Female	26	65	19	16			
Q2 (f)	*Is this experiment interesting*						
Male	30	60	27	13	2.9	2	ns
Female	26	62	11	27			
Q2 (g)	*Is this experiment well-organised*						
Male	30	60	17	23	0.1	2	ns
Female	26	58	18	24			

Table (9.11): *Question (3): Gender opinions about first experiment (a, b, c, d, e, f)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q3 (a)	*I found discussions boring.*						
Male	30	67	10	23	0.9	1	ns
Female	26	50	15	35			
Q3 (b)	*I enjoyed working with members of my group.*						
Male	30	63	10	27	0.6	2	ns
Female	26	54	15	31			
Q3 (c)	*Most of the ideas were not helpful.*						
Male	30	47	20	33	5.9	3	ns
Female	26	69	19	12			
Q3 (d)	*Most of the ideas came from one person.*						
Male	30	40	30	30	1.7	1	ns
Female	26	77	8	15			
Q3 (e)	*Working as a group made it easier for us to get answers.*						
Male	30	73	4	23	0.9	1	ns
Female	26	62	15	23			
Q3 (f)	*I did not respect ideas from others since they are always wrong.*						
Male	30	70	10	20	0.4	1	ns
Female	26	61	12	27			

There are no statistically significant differences on the basis of gender.

Having looked at the student opinions by gender for experiment 1, there is almost no evidence that men and women hold different perceptions. However, it is more important to look at their performance in the post-laboratory exercise for this gives some evidence of enhanced understanding. This is considered next.

9.2.5 Gender with Pre-Laboratory Exercise Group

Table (9.12): *Patterns of scores of the students in laboratory marks, by gender*

	Scores					
Group	**4/10**	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
Male	3%	0%	10%	10%	60%	17%
Female	4%	11%	8%	23%	27%	27%

Table (9.13): *t-test for laboratory marks, by gender*

Group	N	Mean	S. D.	t value	Significance
Male	30	7.7	1.08	1.02	ns
Female	26	7.4	1.47		

From Table 9.13, it can be seen that men and women perform equally well in the post-laboratory exercise for experiment 1. This is consistent with the absence of difference in their perception, by gender.

9.3 Second Experiment

9.3.1 Students Opinions about Second Experiment

As before, Tables 9.14 and 9.15 include only the positive version of the question which are referred by (a, b, d, k, l, m, n, p, q, and r).

Table (9.14): *Question (1): Students' opinions about second experiment (a, b, d, k, l)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
With Pre-lab	56	68	9	23	31.0	4	< 0.001
Without Pre-lab	50	34	10	56			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
With Pre-lab	56	67	7	25	33.1	2	< 0.001
Without Pre-lab	50	32	12	56			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
With Pre-lab	56	62	13	25	43.4	4	< 0.001
Without Pre-lab	50	26	10	64			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
With Pre-lab	56	71	11	18	63.9	3	< 0.001
Without Pre-lab	50	26	12	62			
Q1 (l)	*It was easy to follow the laboratory manual*						
With Pre-lab	56	71	11	18	41.2	4	< 0.001
Without Pre-lab	50	34	12	54			

From Table 9.14, it can be seen that the opinions of students in '*with pre-laboratory group*' are very markedly more positive when compared to the opinions of students in '*without pre-laboratory exercise group*'.

In every item in Table 9.15 below, the "*with pre-laboratory group*' was very markedly more positive than the '*without pre-laboratory exercise group*'. Thus, the pre-laboratory experience here made the apparatus easier to use, helped them to complete the experiment in the prescribed time, the experimental procedure was much clearer, they can use their knowledge in other contexts, also helped them to understand some of the course work.

Table (9.15): *Question (1): Students' opinions about second experiment (m, n, p, q, r)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
With Pre-lab	56	62	13	25	32.0	4	< 0.001
Without Pre-lab	50	30	12	58			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
With Pre-lab	56	75	11	14	16.6	3	< 0.001
Without Pre-lab	50	50	10	40			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
With Pre-lab	56	64	13	23	45.7	4	< 0.001
Without Pre-lab	50	24	10	66			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
With Pre-lab	56	62	9	29	4 7.3	4	< 0.001
Without Pre-lab	50	24	10	66			
Q1 (r)	*The experiment helped me to understand some of the course work*						
With Pre-lab	56	70	11	19	87.7	3	< 0.001
Without Pre-lab	50	20	14	66			

Referring to Table 9.16, in all areas, the students in '*with pre-laboratory group*' hold much more positive attitudes.

Table (9.16): *Question (2): Students' opinions about second experiment (a, b, c, d, e, f, g)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
With Pre-lab	56	77	16	7	32.3	3	< 0.001
Without Pre-lab	50	42	26	32			
Q2 (b)	*Is this experiment helpful*						
With Pre-lab	56	68	21	11	25.6	4	< 0.001
Without Pre-lab	50	38	32	30			
Q2 (c)	*Is this experiment meaningful*						
With Pre-lab	56	59	23	18	32.3	4	< 0.001
Without Pre-lab	50	34	28	38			
Q2 (d)	*Is this experiment understandable*						
With Pre-lab	56	66	23	11	59.4	4	< 0.001
Without Pre-lab	50	24	30	46			
Q2 (e)	*Is this experiment satisfying*						
With Pre-lab	56	58	27	15	27.9	4	< 0.001
Without Pre-lab	50	30	32	38			
Q2 (f)	*Is this experiment interesting*						
With Pre-lab	56	63	23	14	17.9	4	< 0.01
Without Pre-lab	50	36	34	30			
Q2 (g)	*Is this experiment well-organised*						
With Pre-lab	56	59	23	18	14.5	4	< 0.01
Without Pre-lab	50	40	26	34			

Table (9.17): *Question (3): Students' opinions about second experiment (a, b, c, d, e, f)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q3 (a)	*I found discussions boring.*						
With Pre-lab	56	53	2	45	4.6	2	ns
Without Pre-lab	50	58	10	32			
Q3 (b)	*I enjoyed working with members of my group.*						
With Pre-lab	56	59	0	41	2.6	2	ns
Without Pre-lab	50	68	10	22			
Q3 (c)	*Most of the ideas were not helpful.*						
With Pre-lab	56	57	5	38	6.1	2	< 0.05
Without Pre-lab	50	66	10	24			
Q3 (d)	*Most of the ideas came from one person.*						
With Pre-lab	56	68	11	21	0.6	4	ns
Without Pre-lab	50	68	10	22			
Q3 (e)	*Working as a group made it easier for us to get answers.*						
With Pre-lab	56	54	14	32	4.4	4	ns
Without Pre-lab	50	66	12	22			
Q3 (f)	*I did not respect ideas from others since they are always wrong.*						
With Pre-lab	56	59	5	36	2.9	2	ns
Without Pre-lab	50	62	12	26			

From Table 9.17, it can be seen that the difference was significant in one category but not in others.

9.3.2 Summary

Overall, the results from the comparisons between the '*with pre-laboratory group*' and the '*without pre-laboratory group*' show many statistically significant differences. However, when thinking of the ways they work with others in the laboratory 9.17, there are almost no significant differences. Nonetheless, the outcomes from the post-laboratory exercises are more important as an indicator of enhanced understanding.

9.3.3 Comparison of the Scores for Second Experiment

Table (9.18): *Patterns of scores of the students in laboratory marks, by group*

Group	***Scores***					
	4/10	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
With Pre-lab	2%	14%	14%	4%	43%	23%
Without Pre-lab	20%	22%	20%	20%	18%	0%

Table (9.19): *t-test for laboratory marks, by group*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
With Pre-lab	56	7.4	1.4	4.80	$p<0.001$
Without Pre-lab	50	6.1	1.5		

From Table 9.18 and 9.19, the students in the '*with pre-laboratory group*' perform very much better than the '*without pre-laboratory exercise group*'. Thus, in this experiment, perceptions and performance are significantly better for the '*with pre-laboratory group*'.

Having looked at the overall, gender is now considered.

9.3.4 Males and Females of Experimental Group in Experiment 2

As before, the Tables 9.20, and 9.21 include only the positive version of the questions which are referred by (a, b, d, k, l, m, n, p, q, and r).

Table (9.20): *Question (1): Gender opinions about second experiment (a, b, d, k, l)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Male	30	70	13	17	0.1	1	ns
Female	26	65	4	31			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
Male	30	70	13	17	0.1	1	ns
Female	26	65	0	35			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
Male	30	66	17	17	0.5	1	ns
Female	26	58	8	34			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
Male	30	70	13	17	0.1	1	ns
Female	26	73	8	19			
Q1 (l)	*It was easy to follow the laboratory manual*						
Male	30	80	7	13	2.3	1	ns
Female	26	61	15	24			

Table (9.21): *Question (1): Gender opinions about second experiment (m, n, p, q, r)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
Male	30	67	17	16	0.5	1	ns
Female	26	58	8	34			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
Male	30	83	3	14	2.4	1	ns
Female	26	65	19	16			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
Male	30	73	10	17	2.3	1	ns
Female	26	54	15	31			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Male	30	66	13	21	4.5	2	ns
Female	26	50	8	42			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Male	30	73	13	14	0.4	1	ns
Female	26	66	8	26			

From Table 9.20, although males appear to be more positive than females in all items except one item, there are no gender significant differences.

Consistent with the previous findings, Tables 9.21 above and 9.22 below show no significant differences relating to gender.

Table (9.22): *Question (2): Gender opinions about second experiment (a, b, c, d, e, f, g)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
Male	30	77	13	10	1.6	3	ns
Female	26	77	19	4			
Q2 (b)	*Is this experiment helpful*						
Male	30	70	17	13	4.4	3	ns
Female	26	65	27	8			
Q2 (c)	*Is this experiment meaningful*						
Male	30	70	17	13	7.6	3	ns
Female	26	46	31	23			
Q2 (d)	*Is this experiment understandable*						
Male	30	60	27	13	4.1	3	ns
Female	26	73	19	8			
Q2 (e)	*Is this experiment satisfying*						
Male	30	47	37	16	7.1	3	ns
Female	26	54	31	15			
Q2 (f)	*Is this experiment interesting*						
Male	30	63	23	14	0.1	3	ns
Female	26	50	31	19			
Q2 (g)	*Is this experiment well-organised*						
Male	30	47	27	26	0.2	2	ns
Female	26	54	31	15			

Table (9.23): *Question (3): Gender opinions about second experiment (a, b, c, d, e, f)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q3 (a)	*I found discussions boring.*						
Male	30	47	0	53	2.0	1	ns
Female	26	61	4	35			
Q3 (b)	*I enjoyed working with members of my group.*						
Male	30	50	0	50	2.1	1	ns
Female	26	69	0	31			
Q3 (c)	*Most of the ideas were not helpful.*						
Male	30	54	3	43	0.9	2	ns
Female	26	61	8	31			
Q3 (d)	*Most of the ideas came from one person.*						
Male	30	60	10	30	2.8	1	ns
Female	26	77	12	11			
Q3 (e)	*Working as a group made it easier for us to get answers.*						
Male	30	43	17	40	2.7	1	ns
Female	26	65	12	23			
Q3 (f)	*I did not respect ideas from others since they are always wrong.*						
Male	30	57	3	40	0.5	1	ns
Female	26	61	8	31			

The aim of this question is to investigate how students interact in the laboratory with their colleagues. In presenting the data, the percentage in the '*positive*' category refers to those who were actually positive. For example, under the first question ('*I found the discussion boring*'), 47% and 61% are shown as positive: these are the responses for the two groups, where the respondents *disagreed* with the statement. Table 9.23 shows no significant differences relating to gender.

9.3.5 Gender with Pre-Laboratory Exercise Group

Table (9.24): *Patterns of scores of the students in laboratory marks, by gender*

	Scores					
Group	**4/10**	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
Male	3%	10%	20%	4%	40%	23%
Female	0%	19%	8%	4%	46%	23%

Table (9.25): *t-test for laboratory marks, by gender*

Group	N	Mean	S. D.	t value	Significance
Male	30	7.4	1.47	-0.24	ns
Female	26	7.5	1.44		

Overall, men and women hold similar views about experiment 2 and their performance is also the same.

9.4 Third Experiment

9.4.1 Students Opinions about Third Experiment

As before, the Tables 9.26, and 9.27 include only the positive version of the question which are referred by (a, b, d, k, l, m, n, p, q, and r).

Table (9.26): *Question (1): Students' opinions about third experiment (a, b, d, k, l)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
With Pre-lab	50	64	12	24	23.9	4	< 0.001
Without Pre-lab	56	43	11	46			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
With Pre-lab	50	70	10	20	16.4	4	< 0.001
Without Pre-lab	56	43	11	46			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
With Pre-lab	50	68	10	22	28.9	4	< 0.001
Without Pre-lab	56	34	11	55			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
With Pre-lab	50	64	10	26	47.6	4	< 0.001
Without Pre-lab	56	23	13	64			
Q1 (l)	*It was easy to follow the laboratory manual*						
With Pre-lab	50	66	8	26	11.2	2	< 0.01
Without Pre-lab	56	43	13	44			

Table 9.26 show that the students in '*with pre-laboratory group*' are more positive than '*without pre-laboratory exercise*' as in the previous experiment, and all the comparisons are highly significant.

From Table 9.27 below, in four of the five items, the '*with pre-laboratory group*' was more positive than the '*without pre-laboratory exercise group*'. The pre-lab exercise was functioning to make apparatus handling easier and the procedure clearer while relating the experiment to course work and being able to apply it was seen as improved.

Table (9.27): *Question (1): Students' opinions about third experiment (m, n, p, q, r)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
With Pre-lab	50	64	8	28	9.1	2	< 0.05
Without Pre-lab	56	43	13	44			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
With Pre-lab	50	76	4	20	4.0	2	ns
Without Pre-lab	56	62	13	25			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
With Pre-lab	50	66	16	18	26.0	3	< 0.001
Without Pre-lab	56	36	11	53			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
With Pre-lab	50	62	18	20	28.0	4	< 0.001
Without Pre-lab	56	34	11	55			
Q1 (r)	*The experiment helped me to understand some of the course work*						
With Pre-lab	50	68	10	22	33.0	4	< 0.001
Without Pre-lab	56	36	14	50			

Table (9.28): *Question (2): Students' opinions about third experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
With Pre-lab	50	60	28	12	7.0	3	ns
Without Pre-lab	56	50	25	25			
Q2 (b)	*Is this experiment helpful*						
With Pre-lab	50	66	26	8	17.9	3	< 0.001
Without Pre-lab	56	34	30	36			
Q2 (c)	*Is this experiment meaningful*						
With Pre-lab	50	60	22	18	35.2	3	< 0.001
Without Pre-lab	56	29	32	39			
Q2 (d)	*Is this experiment understandable*						
With Pre-lab	50	74	10	16	64.1	2	< 0.001
Without Pre-lab	56	25	23	52			
Q2 (e)	*Is this experiment satisfying*						
With Pre-lab	50	60	32	8	37.7	3	< 0.001
Without Pre-lab	56	25	23	52			
Q2 (f)	*Is this experiment interesting*						
With Pre-lab	50	58	22	20	19.7	3	< 0.001
Without Pre-lab	56	30	30	40			
Q2 (g)	*Is this experiment well-organised*						
With Pre-lab	50	58	22	20	48.4	3	< 0.001
Without Pre-lab	56	21	25	54			

Table (9.29): *Question (3): Students' opinions about third experiment (a, b, c, d, e, f)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q3 (a)	*I found discussions boring.*						
With Pre-lab	50	60	0	40	18.0	3	< 0.001
Without Pre-lab	56	57	14	29			
Q3 (b)	*I enjoyed working with members of my group.*						
With Pre-lab	50	58	0	42	0.2	2	ns
Without Pre-lab	56	54	13	32			
Q3 (c)	*Most of the ideas were not helpful.*						
With Pre-lab	50	58	12	30	1.7	4	ns
Without Pre-lab	56	57	11	32			
Q3 (d)	*Most of the ideas came from one person.*						
With Pre-lab	50	54	16	30	1.1	4	ns
Without Pre-lab	56	61	12	27			
Q3 (e)	*Working as a group made it easier for us to get answers.*						
With Pre-lab	50	58	14	28	1.4	4	ns
Without Pre-lab	56	64	13	23			
Q3 (f)	*I did not respect ideas from others since they are always wrong.*						
With Pre-lab	50	56	12	32	2.3	4	ns
Without Pre-lab	56	64	13	23			

From Table 9.28, in most items, the '*with pre-laboratory group*' are very much more positive than the '*without pre-laboratory exercise group*'.

The aim of this question is to investigate how students interact in the laboratory with their colleagues. From Table 9.29 in only one question are the two groups showing a significant difference. The '*with pre-laboratory exercise group*' hold more polarised views.

9.4.2 Summary

Overall, the students in the '*with pre-laboratory group*' are more optimistic than '*without pre-laboratory exercise group*'. 16 responses out of twenty-three from the comparison were significant. However, performance is a better indicator of effeteness.

9.4.3 Comparison of the Scores for Third Experiment

Table (9.30): *Patterns of scores of the students in laboratory marks, by group*

Group	***Scores***					
	4/10	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
With Pre-lab	6%	10%	10%	10%	34%	30%
Without Pre-lab	21%	25%	16%	20%	18%	0%

Table (9.31): *t-test for laboratory marks, by group*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
With Pre-lab	50	7.5	1.56	5.45	p<0.001
Without Pre-lab	56	5.9	1.43		

The students in the '*with pre-laboratory group*' achieved markedly higher scores in the post laboratory exercise than students in the '*without pre-laboratory exercise groups*'.

Having looked at the overall, gender is now considered.

9.4.4 Males and Females of Experimental Group in Experiment 3

As before the Tables 9.32, and 9.33 include only the positive of the question questions which are referred by (a, b, d, k, l, m, n, p, q, and r).

From Table 9.32 below, there are no significant differences except in considering the interest generated in the topic where the views of the women appear more positive.

Table (9.32): *Question (1): Gender opinions about third experiment (a, b, d, k, l)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Male	26	61	8	31	0.1	1	ns
Female	24	67	17	16			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
Male	26	69	12	19	0.1	2	ns
Female	24	71	8	21			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
Male	26	65	8	27	10.1	1	< 0.01
Female	24	71	13	16			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
Male	26	65	8	27	0.0	1	ns
Female	24	62	13	25			
Q1 (l)	*It was easy to follow the laboratory manual*						
Male	26	65	8	27	0.0	2	ns
Female	24	67	8	25			

Table (9.33): *Question (1): Gender opinions about third experiment (m, n, p, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
Male	26	69	8	23	0.7	2	ns
Female	24	58	8	34			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
Male	26	77	8	15	0.3	1	ns
Female	24	79	4	17			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
Male	26	73	12	15	1.2	1	ns
Female	24	58	21	21			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Male	26	58	23	19	0.3	1	ns
Female	24	54	8	38			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Male	26	77	8	15	2.0	1	ns
Female	24	58	13	29			

Men and women hold similar views in all items.

Table (9.34): *Question (2): Gender opinions about third experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
Male	26	61	31	8	3.0	3	ns
Female	24	58	25	17			
Q2 (b)	*Is this experiment helpful*						
Male	26	65	31	4	3.2	3	ns
Female	24	67	21	12			
Q2 (c)	*Is this experiment meaningful*						
Male	26	54	12	34	4.1	3	ns
Female	24	50	42	8			
Q2 (d)	*Is this experiment understandable*						
Male	26	81	8	11	3.0	3	ns
Female	24	67	12	21			
Q2 (e)	*Is this experiment satisfying*						
Male	26	65	27	8	1.7	3	ns
Female	24	54	37	9			
Q2 (f)	*Is this experiment interesting*						
Male	26	46	27	27	4.6	3	ns
Female	24	54	33	13			
Q2 (g)	*Is this experiment well-organised*						
Male	26	34	46	20	2.3	3	ns
Female	24	58	21	21			

In addition, from the table above (9.34) statistically there are no gender differences.

Table (9.35): *Question (3): Gender opinions about third experiment (a, b, c, d, e, f)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q3 (a)	*I found discussions boring.*						
Male	26	62	0	38	0.1	1	ns
Female	24	60	0	40			
Q3 (b)	*I enjoyed working with members of my group.*						
Male	26	54	0	46	0.4	1	ns
Female	24	63	0	37			
Q3 (c)	*Most of the ideas were not helpful.*						
Male	26	58	15	27	0.2	1	ns
Female	24	59	8	33			
Q3 (d)	*Most of the ideas came from one person.*						
Male	26	61	12	27	0.2	1	ns
Female	24	46	21	33			
Q3 (e)	*Working as a group made it easier for us to get answers.*						
Male	26	58	15	27	0.1	2	ns
Female	24	58	13	29			
Q3 (f)	*I did not respect ideas from others since they are always wrong.*						
Male	26	58	15	27	0.6	1	ns
Female	24	55	8	37			

The aim of this question is to investigate how students interact in the laboratory with their colleagues. Again statistically there are no gender differences.

9.4.5 Gender with Pre-laboratory Exercise Group

Table (9.36): *Patterns of scores of the students in laboratory marks, by gender*

	Scores					
Group	**4/10**	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
Male	3%	11%	12%	12%	27%	35%
Female	8%	8%	8%	9%	42	25%

Table (9.37): *t-test for laboratory marks, by gender*

Group	N	Mean	S. D.	t value	Significance
Male	26	7.7	1.00	0.69	ns
Female	24	7.5	0.93		

Both men and women performed equally well, on average.

9.5 Fourth Experiment

9.5.1 Students Opinions about Fourth Experiment

As before, the Tables 9.38, and 9.39 include only the positive version of the question which are referred by (a, b, d, k, l, m, n, p, q, and r).

Table (9.38): *Question (1): Students' opinions about four experiment (a, b, d, k, l)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
With Pre-lab	50	70	14	16	32.1	3	< 0.001
Without Pre-lab	56	34	16	50			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
With Pre-lab	50	72	12	16	54.9	3	< 0.001
Without Pre-lab	56	29	12	59			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
With Pre-lab	50	70	6	24	17.6	2	< 0.001
Without Pre-lab	56	41	11	48			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
With Pre-lab	50	68	10	22	34.2	2	< 0.001
Without Pre-lab	56	30	16	54			
Q1 (l)	*It was easy to follow the laboratory manual*						
With Pre-lab	50	64	14	22	13.0	3	< 0.01
Without Pre-lab	56	39	14	47			

In every item in Table 9.38, the "*with pre-laboratory group*' was very markedly more positive than the '*without pre-laboratory exercise group*'. By using pre-laboratory exercise, a significant change occurs in their perceptions.

Table (9.39): *Question (1): Students' opinions about fourth experiment (m, n, p, q, r)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
With Pre-lab	50	68	12	20	44.3	3	< 0.001
Without Pre-lab	56	27	18	55			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
With Pre-lab	50	74	10	16	10.7	3	< 0.05
Without Pre-lab	56	54	14	32			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
With Pre-lab	50	70	16	14	53.5	3	< 0.001
Without Pre-lab	56	27	12	61			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
With Pre-lab	50	74	6	20	25.6	2	< 0.001
Without Pre-lab	56	40	13	47			
Q1 (r)	*The experiment helped me to understand some of the course work*						
With Pre-lab	50	74	10	16	52.7	3	< 0.001
Without Pre-lab	56	28	11	61			

Encouragingly, the majority of students from '*with pre-laboratory group*' expressed their more positive opinions in all areas. Thus, by using pre-laboratory exercise the students find apparatus easier to use, completed the experiment in the prescribed time, and were more able to apply their knowledge in other contexts, and laboratory work helped them to understand the physics topics.

Table (9.40): *Question (2): Students' opinions about fourth experiment (a, b, c, d, e, f, g)*

		%			***Comparisons***		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
With Pre-lab	50	76	16	8	25.2	2	< 0.001
Without Pre-lab	56	43	27	30			
Q2 (b)	*Is this experiment helpful*						
With Pre-lab	50	70	16	14	15.1	2	< 0.001
Without Pre-lab	56	43	29	28			
Q2 (c)	*Is this experiment meaningful*						
With Pre-lab	50	60	28	12	8.1	4	< 0.05
Without Pre-lab	56	43	30	27			
Q2 (d)	*Is this experiment understandable*						
With Pre-lab	50	72	12	16	15.8	2	< 0.001
Without Pre-lab	56	45	32	23			
Q2 (e)	*Is this experiment satisfying*						
With Pre-lab	50	58	26	16	10.3	4	< 0.01
Without Pre-lab	56	36	30	34			
Q2 (f)	*Is this experiment interesting*						
With Pre-lab	50	58	26	16	13.8	4	< 0.01
Without Pre-lab	56	34	36	30			
Q2 (g)	*Is this experiment well-organised*						
With Pre-lab	50	30	38	32	8.7	5	ns
Without Pre-lab	56	23	32	45			

Again, the students in '*with pre-laboratory group*' was more positive than the '*without pre-laboratory exercise group*' in seeing the experiment as useful and helpful. They were also more positive in seeing the experiment as understandable, and interesting. However, only a minority of students from both groups were positive in seeing the experiment as well organised, with the pre-laboratory experience making no difference to laboratory organisation in their opinion.

Table (9.41): *Question (3): Students' opinions about fourth experiment (a, b, c, d, e, f)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q3 (a)	*I found discussions boring.*						
With Pre-lab	50	60	0	40	11.9	2	< 0.01
Without Pre-lab	56	34	16	50			
Q3 (b)	*I enjoyed working with members of my group.*						
With Pre-lab	50	62	0	38	14.4	2	< 0.001
Without Pre-lab	56	38	14	48			
Q3 (c)	*Most of the ideas were not helpful.*						
With Pre-lab	50	50	12	38	0.8	4	ns
Without Pre-lab	56	46	11	43			
Q3 (d)	*Most of the ideas came from one person.*						
With Pre-lab	50	48	14	38	1.2	4	ns
Without Pre-lab	56	52	14	34			
Q3 (e)	*Working as a group made it easier for us to get answers.*						
With Pre-lab	50	52	18	30	2.3	4	ns
Without Pre-lab	56	45	16	39			
Q3 (f)	*I did not respect ideas from others since they are always wrong.*						
With Pre-lab	50	46	22	32	3.0	4	ns
Without Pre-lab	56	47	14	39			

The aim of this question is to investigate how students interact in the laboratory with their colleagues. As seen in the above table, there are significant differences between the two groups in just two areas, so the first group did not see the discussion was boring, also they enjoyed working with member of group more than other groups.

9.5.2 Summary

Overall, the findings from the comparison of the opinions of '*with pre-laboratory group*' and '*without pre-laboratory exercise group*' confirm that pre-lab is making powerful change with the students; differences almost all significant, except five out of twenty three. The performance of students from both groups in the post-lab exercise is now considered.

9.5.3 Comparison of the Scores for Fourth Experiment

Table (9.42): *Patterns of scores of the students in laboratory marks, by group*

Group	***Scores***					
	4/10	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
With Pre-lab	0%	4%	8%	22%	52%	14%
Without Pre-lab	25%	25%	16%	20%	14%	0%

Table (9.43): *t-test for laboratory marks, by group*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
With Pre-lab	50	7.6	0.964	8.21	$p<0.001$
Without Pre-lab	56	5.7	1.408		

From Table 9.42 the t-test result shows that the '*with pre-laboratory group*' outperform the '*without pre-laboratory group*' quite markedly.

Having looked at the overall, gender is now considered.

9.5.4 Males and Females of Experimental Group in Experiment 4

As before, the Tables 9.44, and 9.45 include only the positive version of the questions which are referred by (a, b, d, k, l, m, n, p, q, and r).

Males and females show nearly similar views for the question shown in Tables 9.44 and 9.45

Table (9.44): *Question (1): Gender opinions about four experiment (a, b, d, k, l)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Male	26	77	12	11	1.2	1	ns
Female	24	62	17	21			
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*						
Male	26	81	4	15	2.1	1	ns
Female	24	62	21	17			
Q1 (d)	*Having done this experiment I now find the topic more interesting*						
Male	26	69	12	19	0.0	1	ns
Female	24	71	0	29			
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*						
Male	26	69	4	27	0.0	1	ns
Female	24	66	17	17			
Q1 (l)	*It was easy to follow the laboratory manual*						
Male	26	65	4	31	0.0	1	ns
Female	24	62	25	13			

Table (9.45): *Question (1): Gender opinions about fourth experiment (m, n, p, q, r)*

		%			*Comparisons*		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (m)	*For this experiment it was easy to use the apparatus*						
Male	26	69	12	19	0.0	2	ns
Female	24	66	13	21			
Q1 (n)	*I successfully completed this experiment within the prescribed time*						
Male	26	77	12	11	0.2	1	ns
Female	24	71	8	21			
Q1 (p)	*Experimental procedure was more clear due to my preparation*						
Male	26	77	12	11	1.2	1	ns
Female	24	62	21	17			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Male	26	77	4	19	0.2	1	ns
Female	24	71	8	21			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Male	26	85	8	7	3.2	1	ns
Female	24	62	13	25			

Again, in Table 9.46, males and females show nearly similar views.

Table (9.46): *Question (2): Gender opinions about fourth experiment (a, b, c, d, e, f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (a)	*Is this experiment useful*						
Male	26	82	15	3	2.6	3	ns
Female	24	71	17	12			
Q2 (b)	*Is this experiment helpful*						
Male	26	69	19	12	0.4	3	ns
Female	24	71	12	17			
Q2 (c)	*Is this experiment meaningful*						
Male	26	50	38	12	4.5	3	ns
Female	24	71	17	12			
Q2 (d)	*Is this experiment understandable*						
Male	26	73	8	19	0.9	3	ns
Female	24	70	17	13			
Q2 (e)	*Is this experiment satisfying*						
Male	26	65	16	19	4.7	3	ns
Female	24	50	37	13			
Q2 (f)	*Is this experiment interesting*						
Male	26	62	23	15	4.8	3	ns
Female	24	54	29	17			
Q2 (g)	*Is this experiment well-organised*						
Male	26	31	38	31	0.0	2	ns
Female	24	29	37	34			

Table (9.47): *Question (3): Gender opinions about fourth experiment (a, b, c, d, e, f)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q3 (a)	*I found discussions boring.*						
Male	26	54	0	46	0.9	1	ns
Female	24	67	0	33			
Q3 (b)	*I enjoyed working with members of my group.*						
Male	26	57	0	43	0.4	1	ns
Female	24	67	0	33			
Q3 (c)	*Most of the ideas were not helpful.*						
Male	26	50	8	42	0.4	1	ns
Female	24	50	17	33			
Q3 (d)	*Most of the ideas came from one person.*						
Male	26	58	12	30	1.2	1	ns
Female	24	37	17	46			
Q3 (e)	*Working as a group made it easier for us to get answers.*						
Male	26	50	27	23	3.3	3	ns
Female	24	54	8	38			
Q3 (f)	*I did not respect ideas from others since they are always wrong.*						
Male	26	46	12	42	2.6	1	ns
Female	24	46	33	21			

The aim of this question is to investigate how students interact in the laboratory with their colleagues. Males and females show similar views.

9.5.5 Gender with Pre-Laboratory Exercise Group

Table (9.48): *Patterns of scores of the students in laboratory marks, by gender*

	Scores				
Group	**5/10**	**6/10**	**7/10**	**8/10**	**9/10**
Male	4%	11%	8%	62%	15%
Female	4%	4%	38%	42%	12%

Table (9.49): *t-test for laboratory marks, by gender*

Group	**N**	**Mean**	**S. D.**	**t value**	**Significance**
Male	26	7.7	1.002	0.69	ns
Female	24	7.5	0.932		

Overall, men and women perform equally well and they hold similar opinions.

9.6 Discussion

Looking at the comparisons between the '*with pre-laboratory group*' and '*without pre-laboratory group*' in the survey questions, it has been seen that the '*with pre-laboratory group*' are much more positive in their opinions when compared to the '*without pre-laboratory group*' in every experiment. They found the laboratory experience much more enjoyable, interesting and satisfying; in addition, they also found the lab work helping them more in relation to course work.

The most positive opinions came with the experiment involving Rotation of the plane of polarisation while the determination of wavelength of light from the helium neon laser by using diffraction grating showed the smallest differences.

One the key features is the importance of bringing pre-laboratory experiences, the actual laboratory, including the instructions sheets, as well as the post-laboratory experiences to make a coherent whole. Shah (2004) observed the potentially disastrous outcomes when the pre-laboratory was introduced without adjusting the other aspects of the laboratory experience while Carnduff and Reid (2003) stressed the importance of creating a coherent learning experience.

Students in '*with pre-laboratory group*' expressed their positive views regarding to clear procedure in four experiments. This is very important factor which may affect the learning in the laboratory as mentioned by Johnstone and Al-Shuaili (2001).

Kirschner and Meester (1988) noted the importance of being able to apply what was learnt in the laboratory in other situations. This improved for the '*with pre-laboratory group',* the effect being most marked for experiments 1 (The determination of the refraction index of a glass prism using a spectrometer) and 4 (Rotation of the plane of polarisation with sugar solutions).

Carnduff and Reid (2003) listed *illustrating key concepts* as one reason for inclusion of practical work in undergraduate courses. In addition, Black and Ogborn (1979) put *the lab work could illustrate ideas* in a group as an aim of practical work. The '*with pre-laboratory group*' were markedly more positive in their responses to the item: *The experiment helped me to understand some of the course work.*

The pre-labs for experiments (determination of the refraction index of a glass prism using a spectrometer, determination of wavelength of light from the helium neon laser by using diffraction grating) as used in chapter eight did not make a great impact in terms of students saying that the experiment was meaningful. However, in chapter nine, the expression of meaningfulness rose markedly. This suggests that the changed lab instructions were extremely important for these experiments.

Encouragingly, the '*with pre-laboratory group*' felt that the experiments were much more understandable compared to the same group in the second stage. This could reflect the effect of pre-laboratory exercises and laboratory manual together, and confirm the finding by Johnstone *et al.* (1994) that the reduction in working memory overload allowed more cognitive capacity to make sense of what they were doing.

It is clear that interest and satisfaction is rated more highly by '*with pre-laboratory group*' for some experiments and this is very important in that interest and satisfaction are both important aspects of effective learning.

It is interesting to note that the pre-laboratories did not make any difference in the way the students saw the organisation of the experiment. They probably interpreted this question in terms of the practical lab organisation and this was unaffected by the changes in pre-labs, and the manual. The students tend to hold negative views about the organisation and there is a need for further enquiry to explore the nature of the problem.

Students from both groups '*with pre-laboratory group*' and '*without pre-laboratory group*' were agreed that discussion in laboratory enhanced their understanding. Their responses are consistent with school students and University group in the first stage in this research (how they see discussion in the laboratory enhanced their understanding of the subject, and how they enjoyed the work in groups). This evidence here shows that group work can enhance understanding (consistent with Heller & Mark, 1992). In addition, they were happy to exchange ideas, respect each other and learn from each other.

As in the last stage, the post-laboratory exercises were introduced at the end of each experiment to give a student opportunity to review their work and to apply the ideas gained. The aim is to link the ideas learnt in the actual laboratory to ideas previously learnt. This may lead to richer connections between ideas held in long-term memory. Encouragingly, the performance of the '*with pre-laboratory group*' in the post-laboratory exercises was markedly better than the performance in the '*without pre-laboratory group'*. This is a very strong indication that the pre-laboratory exercises were having the desired effect, and this result support us to use the approach in the future to enhance learning in the laboratory.

As in chapter eight, there is a general tendency for men to appear to hold more positive views but rarely was this significant. This is also consistent with the findings of Skryabina who saw both genders equally interested in Physics but interested in different areas (Reid & Skryabina, 2002). In addition, and despite their different views regarding to the experiments, the performance in the post-laboratory exercises indicated how men and women can perform equally well, overall.

9.7 Result from Interviews

It is important that the university teachers involved in the physics laboratory work are fully integrated into the new way of conducting lab work. For this purpose, several staff were interviewed to gain insights into how they saw the modified process. The sample was 10. The interviews were conducted after all stages of the modifications of the lab work were completed.

For these interviews, specific topics were identified and possible questions prepared. However, freedom was give to the interviewees to extend their responses as they wished and to bring in other themes.

The outcomes from interviews are summarised, each question is shown, the pattern of responses obtained brought together, and all efforts were made to translate typical statements made by university teachers from Arabic to English. The interviews' questions will be in Appendix H.

The interviews focus on three themes:

- Laboratory Physics;
- Pre-Lab exercises;
- Post-Lab exercises.

Each of these three topics is discussed in turn. However, before the talking started on these themes, there were some questions to make the interviewees feel more relaxed and to set them at ease. The questions for this purpose are shown below:

1. Which course do you teach in this semester?
2. Do you prefer teaching at university or to work in other job, such as work in research centre?
3. In general, what are the levels of students when they come from school especially in mathematics and physics? (Or are their background in both subject is good or not?)
4. How long have you taught at the university?

The first theme in interviews was Laboratory Physics. Here are the questions about the first theme:

1. In your opinions, why do you think the students are given practical physics? Or why the syllabus contains practical laboratory?
2. Laboratory work is regarded as an essential part in understanding physics and any science course. What skills might the laboratory work provide to students?

3. Do you think the laboratory as we have them now is the right way for practical work to be effective in reaching their goals? If the answer is no, how we could make the conventional lab more effective?
4. In your opinions what are the difficulties which face the students when they come to laboratory?

The outcomes from interviews are summarised below:

Reasons for practical laboratory physics:

The university teachers think that practical work is very important for the students to introduce equipment as well as to create some kind of reality for the things which they measured. These issues were discussed by Carnduff and Reid (2003) who provided a set of possible reasons for the inclusion of practical work in undergraduate course in chemistry.

University teachers also think practical work could make the subject more interesting and more enjoyable, especially if the practical work is not given by classical way, (they meant conventional laboratory or a laboratory as now). Their reviews are consistent with the findings of Johnstone and Al-Shuaili (2001) who formulated some affective aims for chemistry lab work:

- Interest in the subject.
- Enjoyment of the subject.
- A feeling of reality for chemical phenomena.

In addition, one university teacher said, "*practical work the student confirm what they have taken in lecture* ." This is often the case although, in real science, the theories are more often generated by the laboratory work.

University teachers think the students can learn from the laboratory work by doing with their hands what they have been taught. The idea of learning by doing (John Dewey) needs careful thought for the evidence shows that doing does not *necessarily* generate better understanding. It depends of what is done and, more importantly, how it is done (Johnstone & Wham, 1982). The key lies in working within the limitations of working memory capacity as Kirschner *et al.* (2006) have demonstrated.

Skills from Laboratory work:

The university teachers think the laboratory work provides the students with many skills, including developing confidence, increasing their ability to gather and interpret data. Furthermore, students will know more about how to make a good graph and to compile a good report as well as other important skills, such as social skills from working in groups. Their opinions are entirely consistent with the results of previous research (Kempa & Ward, 1988; Johnstone & Wood, 1977; Lycnh & Ndyetabura, 1983; Meester & Maskill, 1994; Laws, 1996; Bennett & O'Neale, 1998a).

Laboratory Effectiveness:

All university teachers believe that the conventional laboratory is not the right way to achieve the aims and the goals of the laboratory. The conventional laboratory can be described in terms of set experiments, mainly of a verification nature, where students follow prescribed instructions to gain prescribed answers. They consistently emphasised the necessity for change from this type of laboratory. Some of them suggested written material parallel to what was developed in this study; others mentioned computer simulation.

Difficulties students face:

When the university teachers were asked about the difficulties facing students in laboratory, they believe that most students have not enough background, some of them just in physics, and others in both physics and mathematics.

The second theme in the interviews was about the pre-laboratory exercises which were used in this research as a new approach. Here are the questions about the second theme:

1. What is your opinion about pre-lab which we had used?

2. Do you think the pre-labs facilitate the learning in the laboratory and raise comprehension and skills or not?
3. Does pre-lab help in understanding the nature of the experiment?
4. Although the pre-lab was seen as a supplement to real laboratory it was also regarded as a kind of extension of the laboratory time, do you think that or not?
5. Do you think the pre-lab provide support for those with less developed cognitive skills? Does it reduce student cognitive load?
6. What other types of pre-lab could we use beside written material?
7. What are the most important advantages and disadvantages in the pre-lab which we have used?
8. If you want to talk to your colleagues at other university, what are you going to tell them about pre-lab?

Consistently, the university teachers though the pre-lab is a very good way to develop the laboratory as well as to prepare the students for doing new experiments. They believe that the pre-labs facilitate the learning, also contributing to understanding the nature of the experiments. In addition, they felt that pre-labs improve understanding and they saw the pre-lab as a link between theory and practical.

No one saw the pre-lab as an extra time demand. Indeed, they saw the pre-lab as containing useful and important information which reduce the time of doing the experiment. They considered that the pre-lab did reduce the cognitive load on the students (although it is not certain that they grasped what was meant fully). Johnstone and El-Banna (1989) found that "*when the student working memory capacity is exceeded, there is a sharp drop in performance, but some students (~10%) continue to operate efficiently with problems which exceed their capacity; they are probably employing chunking devices that enable them to reduce the problem demand to less than their limit of capacity*".

Most of them believe that computer simulation is a right way alongside the written material. When asked about the greatest advantage and disadvantage of the pre-lab exercises which were used in this study, most of them emphasised that the pre-labs were simple. In addition, the information in the pre-lab is considered as very clear, not complicated, and is not available in the instruction sheet. They noted how the pre-lab also made the experiment related to students' daily life, seen as an important goal for laboratory work.

In the last question in this part, it is suggested that the university teachers are going to tell their colleagues about this new approach, explaining the idea, as well as advising them to use it in any science subject.

The last theme in these interviews is about post-labs. Here are the questions about the third theme:

1. What are your opinions about the post-labs which we had used?
2. What are the advantage and disadvantage of the post-labs which we have used?
3. Do you think by post-labs we can check students understanding of the experiment?
4. Do you use post-lab in your practical course?

All the university teachers believe that the post-labs is good idea to check the students' understanding for the experiments. In addition, they think the most important advantage of these post-labs are to make links between the experiment and daily life. In addition, they believe that the pre-labs, instruction sheets, and post-labs complement each other.

When the interviewer asked them about whether they have used post-labs or something near to this idea, some of them have idea about it, but they did not use it.

However, two of them have used this idea, even it is not recommended from the department, but in informal way.

9.8 Summary of third stage

Table 9.50, provided at the end of the chapter, attempts to draw together some of the main findings for stage 3, experiment by experiment.

9.9 Conclusions

1. In most of the survey items, the responses of the '*with pre-laboratory group*' were significantly more positive than the responses from the 'without pre-laboratory group' (only 23 out of 92 showed no significant difference).
2. The differences in responses to survey items were greatest for experiment 2 and 4, and least for experiment 3.
3. By using the pre-laboratory exercises, new instruction sheets, and post lab together, they improved the perceived ability to apply the ideas learnt to a satisfactory level.
4. The laboratory organisation received a slightly better rating than the second stage. Some of the staff had changed but the pre-labs and post-labs did not aim to change laboratory organisation.
5. In four experiments, the level of understanding as measured by the post-lab exercises, and the improved performance of the '*with pre-laboratory group*' in the post-laboratory exercises was highly significant.
6. In four experiments, the improved performance of the '*with pre-laboratory group*' in the post-laboratory exercises showed no difference with gender.

7. In almost no survey items in all experiments were there differences in response patterns with gender (3 of 68), two items in experiment (1) where males are more positive, and one item in experiment three showed differences where the females were more positive.

In stage 2, pre-labs have been shown to bring benefit to the students in terms of their performance in the past-lab exercises. However, the pre-labs were simply added to an existing laboratory procedure. In stage 3, the same pre-labs were used but the instructions sheets which make up the laboratory manual were completely re-cast. The question is what difference the revised laboratory manual brought about. The next chapter will offer a comparison between the findings from the second and third stages to explore this question.

Table (9.50): *Summary of chapter 9 results*

	Statements with significant differences	With pre-lab versus Without Pre-lab				Male versus Female - with pre-lab group			
		Experiment				Experiment			
		1	2	3	4	1	2	3	4
1-a	The experiment was easy to do	Y	Y	Y	Y	N	N	N	N
1-b	The purpose of this experiment was very clear to me when I started the lab work	Y	Y	Y	Y	Y	N	N	N
1-d	Having done this experiment I now find the topic more interesting	Y	Y	Y	Y	Y	N	Y	N
1-k	The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing.	Y	Y	Y	Y	N	N	N	N
1-l	It was easy to follow the laboratory manual	Y	Y	Y	Y	N	N	N	N
1-m	For this experiment it was east to use the apparatus	Y	Y	Y	Y	N	N	N	N
1-n	I successfully completed this experiment within the prescribed time	Y	Y	N	Y	N	N	N	N
1-p	Experimental procedure was more clear due to my preparation	Y	Y	Y	Y	N	N	N	N
1-q	Having done this experiment, I can see how to apply my knowledge in other contexts	Y	Y	Y	Y	N	N	N	N
1-r	The experiments helped me to understand some of the course work	Y	Y	Y	Y	N	N	N	N
2-a	Is this experiment useful	Y	Y	N	Y	N	N	N	N
2-b	Is this experiment helpful	Y	Y	Y	Y	N	N	N	N
2-c	Is this experiment meaningful	N	Y	Y	Y	N	N	N	N
2-d	Is this experiment understandable	Y	Y	Y	Y	N	N	N	N
2-e	Is this experiment satisfying	Y	Y	Y	Y	N	N	N	N
2-f	Is this experiment interesting	Y	Y	Y	Y	N	N	N	N
2-g	Is this experiment well-organised	Y	Y	Y	N	N	N	N	N
3-a	I found discussions boring	N	N	Y	Y	N	N	N	N
3-b	I enjoyed working with members of my group	N	N	N	Y	N	N	N	N
3-c	Most of the ideas were not helpful	Y	Y	N	N	N	N	N	N
3-d	Most of the ideas came from one person	N	N	N	N	N	N	N	N
3-e	Working as a group made it easier for us to get answers	N	N	N	N	N	N	N	N
3-f	I did not respect ideas from others since they are always wrong	N	N	N	N	N	N	N	N
	Significant performance difference	Y	Y	Y	Y	N	N	N	N

(Y) for significant, (N) for insignificant.

Chapter 10

Comparison of the last two stages

10.1 Introduction

This study has been carried out in three stages. Stage (1) aimed to identify the strengths and weaknesses of current provision in physics laboratory learning in higher education at Sebha University (a typical university in Libya). In the light of the findings, Stage (2) developed and used a set of pre-laboratory exercises to explore their effect in terms of understanding physics as well as student reactions. The outcomes were very positive.

Stage 3 then involved the use of the same pre-laboratory exercises, along with re-designed laboratory instruction sheets and more extensive post-laboratory exercises. Again, the findings were very positive in terms of increased understanding and positive attitudes.

It is possible to compare the perceptions of students in stage (2) and stage (3). This will give some indication of any differences caused by the re-written laboratory instruction sheets and more extensive post-laboratory exercises. In his early work, Johnstone *et al.* (1998) noted that the overload of limited working memory capacity was the source of difficulties in laboratory learning. They predicted that the pre-laboratory exercise was the key to reduce this problem. Comparing stage (2) and stage (3) may give some insights into whether other factors (re-written laboratory instruction sheets and more extensive post-laboratory exercises) are also as important.

This chapter seeks to compare the views of the students who undertook the pre-laboratory exercises in stages (2) and (3). .

The outcomes from the second and third stage will be presented and compared. Thus, in this chapter, the data from the questionnaires which were used at the end of the selected experiments will be summarised and discussed. For each question, a table will show the percentages of students selecting each of the responses, as discussed in chapter six.

Responses to the questions from '*with pre-laboratory group*' in the two stages will be compared, using contingency chi-square, to see where there are significance changes.

The sample for the second stage was 95 students from undergraduate students, fifth semester. Some of them worked with pre-laboratory exercises while the others worked without pre-laboratory exercises. 50 students worked without pre-lab for first three experiments and 45 students worked with pre-lab for the first three experiments. For the other two experiments, these two groups were interchanged. The sample for the second stage was 95 students from undergraduate students, fifth semester, some of them worked with pre-laboratory exercise, while the other worked without pre-laboratory exercise, 50 students worked without pre-lab for just two experiments and 45 students worked with pre-lab for the other two experiments, then these two groups were interchanged.

The sample for the third stage was 106 students, also from undergraduate students, fifth semester laboratory work. Some of them worked with pre-laboratory exercise, while the others worked without pre-laboratory exercises. 50 students worked without pre-lab for first two experiments and 56 students worked with pre-lab for first two experiments. As before, these two groups were interchanged, 50 students worked with pre-lab for the other two experiments, while 56 students worked without pre-lab for the other two experiments.

10.2 The Comparisons

The responses for four experiments are compared. The students in the third stage did not undertake the fifth experiment used in the second stage. Therefore, data for the fifth experiment is not included. The four experiments are summarised in Table 10.1.

Table (10.1): *Title of selected experiments*

	Title	Description
1	Refractive Indices	The determination of the refraction index of a glass prism using a spectrometer.
2	Wavelength of sodium light	Determination of the wavelength of sodium light by using Newton's Rings.
3	Wavelength of light (helium neon laser)	Determination of wavelength of light from the helium neon laser by using diffraction grating.
4	Rotation of the plane of polarisation	Rotation of the plane of polarisation with sugar solutions.

For each of the four experiments, the data from 17 questionnaire items were analysed, giving 68 comparisons overall. It was found that significant differences between the response patterns of stage (2) and stage (3) students only occurred in 9 of the 68 comparisons. These are now shown.

10.2.1 First Experiment

Table 10.2 shows the comparisons between students' opinions in pre-lab group in the third stage (3) and pre-lab group in the second stage (2).

Table (10.2): *Question (2): Students' opinions about first experiment (f, g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (f)	*Is this experiment interesting*						
Pre-lab group (3)	56	61	20	19	11.8	3	< 0.01
Pre-lab group (2)	45	69	15	16			
Q2 (g)	*Is this experiment well-organised*						
Pre-lab group (3)	56	59	18	23	17.4	3	< 0.001
Pre-lab group (2)	45	31	58	11			

From Table 10.2 students in the third stage believe that the organisation is much better and there is a slightly difference in their views the experiment being interesting.

10.2.2 Second Experiment

Table (10.3): *Question (1): Students' opinions about second experiment (q)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Pre-lab group (3)	56	62	9	29	10.6	3	< 0.05
Pre-lab group (2)	45	67	22	11			

The students from stage (3) are not so convinced about being able to apply their knowledge.

Table (10.4): *Question (2): Students' opinions about second experiment (g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (g)	*Is this experiment well-organised*						
Pre-lab group (3)	56	59	23	18	16.0	3	< 0.01
Pre-lab group (2)	45	24	60	16			

From Table 10.4 the students from stage 3 consider that the organisation was better.

10.2.3 Third Experiment

Table (10.5): *Question (2): Students' opinions about third experiment (g)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (g)	*Is this experiment well-organised*						
Pre-lab group (3)	50	58	22	20	10.0	2	< 0.01
Pre-lab group (2)	45	36	53	11			

The stage 3 students see the organisation as better although as with experiments 1 and 2, there is increased polarisation of view with the stage 3 students in Table 10.5.

10.2.4 Fourth Experiment

Table (10.6): *Question (1): Students' opinion about fourth experiment (a, q, r)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q1 (a)	*This experiment was easy to do*						
Pre-lab group (3)	50	70	14	16	10.3	3	< 0.05
Pre-lab group (2)	50	66	0	34			
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*						
Pre-lab group (3)	50	74	6	20	34.0	1	< 0.001
Pre-lab group (2)	50	16	28	56			
Q1 (r)	*The experiment helped me to understand some of the course work*						
Pre-lab group (3)	50	74	10	16	8.1	3	< 0.05
Pre-lab group (2)	50	60	24	16			

In three areas, the students in the third stage were more positive: experiment easy to do, applying knowledge in other contexts (very markedly), understanding some of the course work,

Table (10.7): *Question (2): Students' opinion about fourth experiment (f)*

		%			Comparisons		
Group	**N**	**positive**	**neutral**	**negative**	χ^2	**df**	**p**
Q2 (f)	*Is this experiment interesting*						
Pre-lab group (3)	50	58	26	16	9.4	3	< 0.05
Pre-lab group (2)	50	40	52	8			

The students from stage (3) see this experiment more interesting than the students in stage (2).

10.3 Discussion

From the responses of students from both stages, it could be noted the following:

- In the vast majority of items 59 of 68, there are no significant differences. This shows that the improvements in the way the students see the laboratories is largely due to the introduction of the pre-laboratory exercises. The revisions of the laboratory instruction sheets, although desirable, have not made much difference to the perceptions of the students.
- Where there are significant differences, the stage 3 students tend to be more positive in most cases.
- Where the response patterns in stage 3 are more positive than stage (2), three relate to organisation, while two items indicate increased interest, one indicates greater confidence in applying ideas and one suggests better understanding and one suggest the experiment was easier.

Of course, the questionnaire outcomes merely indicate what the students think. However, it is encouraging that the pre-labs have generated views which are consistently more positive. The revision of the instruction sheets has not changed these views much.

10.4 Summary

Table 10.8 brings the patterns of findings the second and third stages together in a summary form. This seeks to offer a quick overview of the findings.

Table (10.8): *Comparisons between stage 2 and stage 3*

	Expt 1	**Expt 2**	**Expt 3**	**Expt 4**
Exptl/control comparisons (2)	16 - 1	17 - 0	10 - 7	14 - 3
Exptl/control comparisons (3)	16 - 1	17 - 0	15 - 2	16 - 1
% of Ability to apply knowledge (2)	49	67	60	16
% of Ability to apply knowledge (3)	62	62	62	74
% of Understanding (2)	62	69	71	76
% of Understanding (3)	66	66	74	72
% of Organisation (2)	31	24	36	34
% of Organisation (3)	59	59	58	30
% of Satisfying (2)	48	38	57	38
% of Satisfying (3)	61	58	60	58
% of Interesting (2)	69	49	44	40
% of Interesting (3)	61	63	58	58
Female/Male (2)	ns.	ns.	ns.	ns.
Female/Male (3)	ns.	ns.	ns.	ns.
Males >female (2)	12	3	0	1
Males >female (3)	12	12	8	13

The first and second rows indicate the proportion of items where the '*with pre-laboratory group*' responded more positively (statistically) compared with the items where there were no differences. The patterns are very similar in both stages. Looking at all four experiments together, positive statistical differences were found in

57 of 68 in stage two while positive statistical differences were found in 64 of 68 in stage three.

The next ten rows refer to specific features. Thus, for experiment 1 in the third stage, 62% felt they could apply what they had learnt in other contexts, 66% felt they understood it, and so on. The percentages are the percentages of the students who selected the positive two boxes in each item. The percentages are numerically consistently more positive for stage (3) (across all four experiments) in looking at organisation and the experiment being seen as satisfying.

The laboratory organisation received a consistently poor rating in the second stage while the rating in the third stage became higher. However, the views are still not very positive especially in the fourth experiment. This improvement could be because the change in technician of the laboratory or the staff of this course. Indeed, the introduction of the changes may well have affected the staff involved. The actual changes introduced were unrelated to laboratory organisation.

The differences in responses to survey items in third and second stage were greatest for experiment 3 and least for experiment 2 in both stages. The reason is probably simply the nature of the experiments.

In all the experiments in both stages, the improved performance of the '*with pre-laboratory group*' in the post-laboratory exercises showed no difference with gender. However, the men were more positive in several items. This is important. The introduction of the pre-labs brought equal benefits to both genders despite the fact that the men were more positive. This shows the need to treat survey responses with caution: they may not indicate what is really happening.

10.5 Conclusions

Johnstone *et al.* (1998) established that student success in understanding was determined by the cognitive load of the task to be undertaken related to the capacity of the working memory. Thus, if the working memory becomes overloaded, than there is a sharp drop in student performance. In this, the cognitive load can be described as the number of ideas or procedures which have to held in the working memory at the same time in order for success to be possible, It was argued that there were two ways to minimise this effect:

- The teacher controls the rate of information flow so that overload is less likely;
- The amount of distracting information in the process of learning is minimised.

In the laboratory, students often resort to following the instructions as they might follow a recipe. Johnstone *et al.* (1994) observed that this strategy occurred when the student was overwhelmed with information (written material, oral instruction, skill to be recalled, theory to be recalled, and also, observation and deduction to make, plus language and mathematical hurdles). If the student knows that the assessment depends on a written report with a 'correct' result, then recipe following is the best way for success. Understanding is lost.

Meaningful learning occurs when new ideas are linked correctly to ideas previously held. The ideas are stored in long-term memory but the process of making sense of the ideas and linking them correctly occurs in the working memory (Johnstone, 1993). Thus, the information from an external source interacts with information from long-term memory to reach to the state of understanding which could be used or stored. For this to happen, the working memory must be able to hold and operate on the information. At the same time, if information comes to the student too fast, the working memory simply cannot cope. This was what Johnstone and Wham (1982) observed so clearly.

Considering the laboratory situation, Kempa and Nicholls (1983) summarised the the way ideas are linked together in the long-term memory and the effect of this on the performance of students as follows:

- Students' performance depends on the degree of concept interlinking existing in long-term memory.
- Students' ability to problem-solve also related to the knowledge and experience laid down in a branched and interlinked network.

This pair of findings is consistent with the way the long-term memory is understood today, in terms of understanding. Understanding involves ideas linked together correctly. This allows the person to apply these ideas and, thus, to solve problems.

This is seen in the laboratory. For meaningful learning to occur, ideas need to be linked together. This linking process occurs in the working memory and the 'product' is stored in the long-term memory. The pre-laboratory exercises offer a way to minimise any working memory overload.

Students need to know what the laboratory is about, what is the theory of the experiment, which apparatus is needed for this experiment, how the apparatus works, what are the hazards from misuse of apparatus. By preparing the mind for learning in this way, the working memory copes better and understanding is enhanced. In addition, the pre-laboratory exercise is also effective in improving students' attitudes about the physics laboratory specifically and about physics in general. The post-laboratory exercise also plays its part. Here, ideas can be applied and extended.

In all of this, the model of information flow which was developed from past research has offered predictions about the ways by which understanding can develop more effectively, (Johnstone, 1997).

The pre-laboratory exercise holds the key. By applying the idea, students in Libya are performing better and their attitudes are becoming more positive.

The next chapter will be the conclusion of this research and the recommendation for next study.

Chapter 11

General Conclusions

11.1 Introduction

In this chapter, a summary of the whole research study will be outlined. The strengths and weaknesses of the study will be considered before considering research for the future arising from the study. Finally, some recommendations for the organisers of Higher Education Physics laboratories in Libya will be presented.

The entire project was based on the faculty of science at Sebha University, a typical university in Libya, drawing its students from typical schools. The project started by considering how students perceived their school experiences in practical physics by looking back at the outset of their university studies. Then, the study focused on how the students saw their university experience in practical physics towards the end of their first semester. This was undertaken using questionnaires designed for the purpose. The plan was to establish a picture of what was going on and where the problems lay.

In the light of the findings, it was decided to develop a new approach to make the laboratory experience more effective for understanding physics by testing out some new approaches with students in Libya. Here, the laboratories are not highly equipped while the staff and the teachers are not trained adequately.

Johnstone had established that the key reason for difficulties in laboratory learning at university was cognitive overload. His work had shown clearly the power of pre-laboratory exercises in increasing learning in inorganic chemistry (Johnstone *et al.*, 1994) and then extended to physics (Johnstone *et al.*, 1998). Their studies found that positive attitudes towards laboratory work also developed. However, this new approach had not been undertaken in a developing country such as Libya. Thus, the next stage of the study here involved the development and use of pre-laboratory exercises. Their effectiveness was measured using post-laboratory exercises that tested understanding and application of ideas while student perceptions were also considered.

One of the major problems in Libya is that references and support materials are not available in the mother language of the students and it is difficult for students to get physics' references in Arabic especially in higher courses. At the same tine, their English is not robust enough to take advantage of references in English. The aim was that the pre-laboratory exercises would reduce the cognitive overload and also give the students access to background materials in Arabic.

It was found from this study that the pre-laboratory exercises improved understanding quite markedly with the students at Sebha University and their attitudes towards the whole pre-laboratory experience was very positive. However, the pre-laboratory exercises and post-laboratory exercises had simply been added on to the laboratories, without modifying the instructions sheets. The final stage involved re-designing the instruction sheets, thus making the entire laboratory experience a more cohesive one.

At the same time, the post-laboratory exercises were extended. The outcomes were considered using performance in the post-laboratory exercises while student opinions were surveyed again.

The findings of the third stage and second stage were compared to see what is new in students' perceptions. The question being explored here was whether the key to the greater success lay in the pre-laboratory exercises on their own or whether the re-written instruction sheets made further major improvements. It was found that there were only very small further improvements, thus confirming that the pre-learning from the pre-laboratory exercises was the key.

Finally, at the end of the third stage, semi-structured interviews were carried out with university teachers to explore the views of university teachers related to physics laboratories in Libya. The interviews were carried out by an experienced academic not involved in this project. This reduced any possibility of interviewer bias. However, the interview schedule was designed by the research although the interviewer was allowed flexibility so that interviewees were able to respond freely. Implementations depends on staff willingness and commitment. Overall, the university teachers were very positively disposed to the pre-laboratory exercises.

11.2 Summary of the Findings

11.2.1 Detailed Summary from First Stage

The following key observations can be made:

- The practical work seems not to be well established in Libyan schools or universities.
- The students prefer written instruction sheets although they believe they ended up following these instructions sheets without understanding what they were doing.
- There is a good linkage between experiments and the relevant theory at the school level.
- University and school students tend to see practical work as useful, helpful interesting and enjoyable, although quite large minorities are negative in these areas.
- The students seemed to be aware of some reasons why laboratory work is an integral part of a physics course, but their reasons were somewhat limited.
- The students at school are looking forward to practical physics because they think now they will be able to do the experiments for themselves.
- The idea of using computer-based simulations is not feasible in school.
- The students prefer the experiment which is relevant to their life, challenging but easy; also they prefer to work in groups.
- Students consider that they learn important issues from practical work: how to take the observations, how they protect themselves from hazards, how to deal with data such as draw graphs.

11.2.2 Detailed Summary from Second Stage

- In almost all the survey items, the responses of the '*with pre-laboratory group*' were significantly more positive than the responses from the '*without pre-laboratory group*'.
- Even using the pre-laboratory exercises did not improve the perceived ability to apply the ideas learnt to a satisfactory level.

- The laboratory organisation received a consistently poor rating; this area needs addressed.
- In four experiments, the improved performance of the '*with pre-laboratory group*' in the post-laboratory exercises was highly significant.
- In the five experiments there is not much difference between males and females.

11.2.3 Detailed Summary from Third Stage

- In almost all the survey items, the responses of the '*with pre-laboratory group*' were significantly more positive than the responses from the '*without pre-laboratory group*'.
- By using the pre-laboratory exercises, new instruction sheets, and post-lab together, they improved the perceived ability to apply the ideas learnt to a more satisfactory level.
- The laboratory organisation received a better rating than the second stage, but still not high. It is possible that this was caused by a change in the staff of the laboratory and not due to using the pre-laboratory exercise.
- In four experiments, the improved performance of the '*with pre-laboratory group*' in the post-laboratory exercises was highly significant.
- As in the last stage, there is little difference between males and females.
- University teachers thought the pre-lab is a very good way to develop the laboratory as well as to prepare the students for doing new experiments. They believe that the pre-labs facilitate the learning. In addition, they felt that pre-labs improve understanding and they saw the pre-lab as a link between theory and practical.
- University teachers saw the potential of using computer simulations as pre-laboratory exercises as well as written materials.
- All the university teachers believe that the post-lab is good idea to check the students' understanding for the experiments.

Overall, comparing the second stage and the third stage revealed little change, suggesting that the key to the performance improvement as well as the changes in student perceptions was largely due to the pre-laboratory exercises.

11.3 Research Goals

1. Review the current situation in university physics in Libya, focusing on one typical university; The current situation at both school and university was reviewed and a picture was obtained of the role and nature of laboratory work in physics.
2. From that review, find out the key areas where improvements are needed to enable learning to be more effective; The key areas were identified and included the problems of the limitations of working memory capacity which tended to generate a culture of 'following a recipe', problem associated with understanding, and weaknesses in organisation at university level.
3. Carry out various adjustments and modifications, all based on past research evidence, and explore what improvements are being achieved; Pre-laboratory exercises were introduced based on past research evidence and found to highly effective in terms of improved understanding.
4. In the light of this, make recommendations of ways by which laboratory work in physics in higher education institutions in Libya can be enhanced. There will be recommendations for laboratory organisers and these are listed in 11.6.

11.4 Limitations in this Study

This study aimed to address the difficulties in developing effective learning experiences by means of laboratory work in Libya. Education has developed vary rapidly in recent decades and it has proved demanding to ensure that lab work learning has kept pace. With resource limitations, lack of experience and training as well as the difficulties which arise because so little resource material is available in Arabic, lab work needs re-thought.

The study only looked at one university (a typical one) but it is likely that what was observed reflects the wider picture. The key finding that the pre-laboratory exercise enhanced understanding markedly is consistent with the finding of Johnstone *et al.* (1998), a study carried out in totally different circumstances. Indeed, it offers yet another confirmation of the key mechanisms that govern the way the brain operates in learning, when seen as understanding.

The sample is inevitably not large and this hindered the detection of any gender differences although it did not restrict confidence in main findings that pre-laboratory exercise enhance understanding.

11.5 Suggestions for Further Study

In essence, this study has demonstrated the power of the short pre-laboratory exercise in make very considerable improvements in student understanding along with enhanced attitudes. A fruitful next stage would be to expand this approach to other subjects (e.g. chemistry, biology) and measure any improved performance.

The power of the pre-laboratory exercise to reduce cognitive overload and thus release working memory capacity for understanding needs explored further. One of the key roles of the laboratory is to allow students to appreciate the way the findings of the sciences derive from the experimental. Measuring this has been pioneered by Al-Ahmadi and Reid (2011, 2012) at school level. Using developments from their measuring approaches, are pre-laboratory exercises capable of enhancing this scientific skill? In this way, laboratory work might reach a higher potential in learning.

Pre-laboratory exercises have been heavily computerised in chemistry in some places (McKelvy, 2000). However, this has not been carried out much in physics and there are no studies which have examined the performance enhancement that might be achieved.

11.6 Recommendation for Laboratory Organisers

There are practical outcomes from the study which can inform the practises of those who organise the laboratories in physics in higher education.

- One of the findings from stage one is that students prefer written instruction sheets. However, such instruction sheets can reduce the laboratory to a '*recipe-following*' exercise. Great care is therefore needed by the writers of such sheets in offering the students the security they seek while not making such sheets too prescriptive.
- The positive responses from students in the second stage and third stage after using pre-laboratory exercises encourage the use of such approaches in the future with all practical courses.

- Consistently, the organisation of the laboratories was criticised. There is a need to talk to the students to explore exactly what they meant and then take the necessary steps to correct any deficiencies.
- Consistent with the findings of Reid and Skryabina (2002), students want to study things that relate to their life and lifestyle, making sense of the world around them. The topics for chosen experiments needs to take this into account carefully.
- It is recommended to use a post-laboratory exercise after each experiment, because post-laboratory exercises can lead student to revise the knowledge and concepts with a view to making new and richer connections in long term memory.

11.7 Final Thought

This study has demonstrated the power and effectiveness of simple pre-laboratory exercises in a typical Libyan university physics course in enhancing understanding in physics. It is hoped that university physics departments throughout Libya will adopt this approach. It has also identified the importance of setting up tight organisation in running university laboratories and, specifically, the need to develop quality instruction sheets which will build coherently on the purposes of the pre-laboratory exercises. Laboratory work has an important role in understanding a subject like physics in that it can make physics more real for the students. More importantly, there is great scope for developing laboratory learning which will enhance understanding as well as give the students an experience of how experimental evidence is used to develop the insights in physics. The hope is that the outcomes of this study will enrich university physics courses in Libya and will fulfil the maxim: *you do not have to change the experiment; you have to change what you do with the experiment* (derived from a quotation in Carnduff & Reid, 2003).

Bibliography

Al-Ahmadi, F. & Reid, N. (2011). Scientific thinking - what is it and can it be measured? *Journal of Science Education*, *11*(2), 53–59.

Al-Ahmadi, F. & Reid, N. (2012). Scientific thinking - can it be taught? *Journal of Science Education*, *13*(1), 18–23.

Ali Hamed, S. (2005). *Attitudes and difficulties in upper school physics in libya* (Master's thesis, University of Glasgow).

Allen, J. B., Barker, L. N. & Ramsden, J. H. (1986). Guided inquiry laboratory. *Journal of chemical education, 63*(6), 533–534.

Al-Shibli, A. (2003). *A study of science student teachers perceptions of learning in the education colleges in the sultanate of oman,* (Doctoral dissertation, University of Glasgow, Glasgow).

American Association of Physics (A.A.P.T.) (1997). Goals of the introductory physics laboratory. *The Physics Teacher*, *35*(9), 546–548.

Anderson, J. R. (1995). *Learning and memory: an integrated approach.* New York, USA: Wiley.

Ashcraft, M. H. (1994). *Human memory and cognition,* New York, USA: HarperCollins.

Atkinson, R. C. & Shiffrin, R. M. (1968). Human memory :aproposed system and its control processes. In K. W. Spence (Ed.), *The psychology of learning and motivation: advances in research and theroy* (Vol. 2, pp. 89–195). New York: Academic Press.

Atkinson, R. L., Atkinson, R. C., Smith, E. E. & Bem, D. J. (1993). *Introduction to psychology* (11th ed.). Fort Worth, USA: HBJ.

Ausubel, D., Novak, J. & Hanesian, H. (1978). *Educational psychology: a cognitive view* (2nd ed.). New York, USA: Holt, Rinehart & Winston.

Ausubel, D. P. (1968). *Education psychology: a cognitive view*. New York: Holt, Rinhart and Winston.

Ausubel, D. P. & Robinson, F. G. (1969). *School learning: an introduction to educational psychology*. New York: Holt, Reinhart and Winston.

Ausubel, D. P., Sullivan, E. V. & Ives, S. W. (1980). *Theory problems of child development*. New York, USA: Grune & Stratton.

Baddeley, A. (1999). *Essentials of human memory*. Hove, England Psychology Press.

Bahar, M. (1999). *Investigation of biology student's cognitive structure through word association tests, mind maps and structural communication grids* (Doctoral dissertation, University of Glasgow.).

Bahar, M., Johnstone, A. H. & Sutcliffe, R. (1999). Investigation of students' cognitive structure in elementary genetics through word association tests. *Journal of Biological Education*, *33*, 134–141.

Barber, P. (1988). *Applied cognitive psychology, an information-processing framework*. New York, USA: Methuen & CO.

Bennett, S. & O'Neale, K. (1998a). Skills development and practical work in chemistry. *University chemistry*, *2*(2), 58–62.

Bennett, S. & O'Neale, K. (1998b). *Progressive development of practical skills in chemistry: a guide to early-undergraduate experimental work*. The Royal Society of Chemistry.

Best, J. W. (1981). *Research in education* (4th edition). Prentice Hall PTR.

Black, P. & Ogborn, J. (1979). Laboratory work in undergraduate teaching, In D. McNally (Ed.), *Learning strategies in university science*. Cardiff: University College Cardiff Press.

Bliss, J. (1995). Piaget and after: the case of learning science. *Studies in Science Education*, *25*(1), 139–172.

Boud, D., Dunn, J. & Hegarth-Hazel, E. (1986). *Teaching in laboratories.* Milton Keynes: Milton Keynes Open University Press.

Bourne, L. F., Doninowski, R. L., Loftus, E. & Healy, A. (1986). *Cognitive processes* [(2nd ed.).:] (2nd). Prentice-Hall International. New Jersey USA.

Bruner, J. (1972). *The relevance of education.* London: Redwood Press Limited.

Bruner, J. S. (1963). *The process of education.* Harvard University Press.

Bruner, J. S. (1966). *Toward a theory of instruction.* Cambridge Mass: Harvard University Press.

Bruner, J. S. (1973). Organisation of early skilled action. *Child Development*, *44*, 1–11.

Bruner, J. S. (1986). *Actual minds, possible worlds.* Cambridge: Harvard University Press.

Brunning, R. H., Schraw, G. J. & Ronning, R. R. (1995). *Cognitive psychology and instruction,:* Englewood, USA: Prentice-Hall Inc.

Buckley, J. & Kempa, R. (1971). Practical work in sixth-form chemistry courses. *School Science Review*, *53*, 24–36.

Carnduff, J. & Reid, N. (2003). *Enhancing undergraduate chemistry laboratories.* The Royal Society of Chemistry, ISBN 0-85404-378-0.

Carpenter & Lehrer. (1999). Teaching and learning mathematics with understanding. In E. Fenema & T. A. Romberg (Eds.), *Classrooms that promote mathematical understanding* (pp. 19–32). Mahwah, USA: Erlbaum.

Case, R. (1974a). Mental strategies, mental capacity, and instruction; a neo-piagetian investigation. *Journal of Experimental Child Psychology*, *18*(3), 382–397.

Case, R. (1974b). Structures and structures, some functional limitations on the course of cognitive growth. *Cognitive Psychology*, *6*(4), 544–574.

Cohen, L. & Manion, L. (1997). *Research methods in education* (4th Ed). London, Routledge.

Curriculum Papers 490. (1962). *Alternative chemistry for ordinary and higher grade.* Scottish Examination Board. Dalkeith Edinburgh: Curriculum Papers.

Curriculum Papers 512. (1962). *Alternative chemistry for ordinary and higher grade.* Scottish Examination Board. Dalkeith Edinburgh: Curriculum Papers.

Dainton, F. (1968). *The dainton report: an inquiry into the flow of candidates into science and technology.* London: HMSO.

Dakheel, A. (1988). *Optics.* Tripoli: Alfrjany.

Deacon, C. & Hajek, A. (2011). Student perceptions of the value of physics laboratories. *International Journal of Science Education, 33*(7), 943–977.

DeBard, R. (2004). Millennials coming to college. *New Directions for Student Services*, *106*(106), 33–45.

Delucchi, K. (1949). Pitfalls with chi-square. *Psychology Bulletin*, *94*, 166–182.

Domin, D. (1999). A review of laboratory instruction styles. *Journal of Chemical Education*, *76*(4), 543–547.

Donaldson, M. (1978). *Children's minds.* Glasgow, UK: William Collins Sons and Co. Ltd.

Downie, A., J.R. Johnstone & Katung, M. (1999). Monitoring attitude change in students to teaching and learning in a university setting: a study using perry's developmental model, *Teaching in Higher Education*, *4*(1), 43–59.

Egan, K. (1983). *Education and psychology: plato, piaget, and scientific psychology.* Teachers College Press, Columbia University, New York ; London.

El-Sawaf, M. (2007). *Educational beliefs development with pre- and in-service teachers using perry's model: a cross-cultural study,* (Doctoral dissertation, University of Glasgow, Glasgow).

Entwistle, N. (1981). *Styles of learning and teaching.* New York: John Wiley.

Entwistle, N. J. (1987). A model of the teaching-learning process. In J. Richardson, M. Eysenck & D. Piper (Eds.), *Student learning: research in education and cognitive psychology* (pp. 13–28). Milton Keynes, UK: Open University Press & SRHE.

Entwistle, N. . J. (2000). Approaches to studying and levels of understanding: the influences of teaching and assessment. *In J. C. Smart (Ed.), Higher Education: Handbook of Theory and Research*, *15*, 156–218.

Entwistle, N. J. & Ramsden, P. (1983). *Understanding student learning.* London: Croom Helm.

Ericsson, K. A. & Kintsch, W. (1995). Long-term working memory. *Psychological Review*, *102*, 211–245.

Fensham, P. J. (2004). *Defining an identity: the evolution of science education as a field of research.*

Fielden, J. & Pearson, P. K. (1978). *Costing educational practice.* London: Council for Education Technology.

Finster, D. C. (1989). Developmental instruction, part 1. perry model of intellectual development. , *Journal of Chemical Education*, *66*(8), 659–661.

Finster, D. C. (1991). Developmental instruction: part ii. application of the pery model to general chemistry. *Journal of Chemical Education*, *67*, 752–756.

Fraenkel, J. & Wallen, N. (2000). *How to design & evaluate research in education.* New York, USA: McGraw-Hill Companies.

Gagné, R. M. (1970). *The conditions of learning.* (2nd ed). Bristol: Rinehart & Winston.

Garrison, D., Andrews, J. & Magnusson, K. (1995). Approaches to teaching and learning in higher education. *New Currents*, *2*(1). Retrieved from http://www.ucalgary.ca/pubs/Newsletters/Currents/Vol2.1/approaches.html.

Gay, L. (1981). *Education research: competencies for analysis and application* (2nd ed). Ohio: Charles E. Merrill Publishing Co.

Gay, L. R. & Airasian, P. (2000). *Educational research: competencies for analysis and application* . Upper Saddle River, NJ: Prentice-Hall, Inc.

Gee, B. & Clack, S. G. (1992). The origine of pracrical work in the english school science curriculum. *Scool Science Review*, *73*(265), 79–83.

Gibbs, G. (1992). *Improving the quality of student learning.* Bristol, UK: Technical and Educational Services Ltd.

Gibbs, G. (1994). *Improving student learning. theory and practice.* Oxford, UK: The Oxford Centre for Staff Development.

Good, T. L. & Brophy, J. E. (1990). *Educational psychology: a realistic approach.* New York, USA: Longman.

Gray, C. (1997). *A study of factors affecting a curriculum innovation in university.* (Doctoral dissertation, University of Glasgow).

Hackling, M. & Garnett, P. (1995, December). The development of expertise in science investigation skills. *Australian Science Teachers Journal*, *41*(4), 80–85.

Halliday, D. & Resnick, R. (1988). *Physics part 1 & 2.* John Wiley & Sons.

Hamachek, D. E. (1995). *Psychology in teaching, learning and growth.* Boston, USA: Allyn and Bacon.

Hanif, M., Sneddon, P., Al-Ahmadi, F. & Reid, N. (2009). The perceptions, views and opinions of university students about physics learning during undergraduate laboratory work. *European Journal of Physics*, *30*(1), 85–96.

Hanson, S. & Overton, T. (2010). *Skills required by new physics graduates and their development in degree programmes.* Higher Education Academy, University of Hull.

Harvey, L., Moon, S., Geall, V. & Bower, R. (1997). *Graduates' work: organisational change and student attributes.* CRQ, AGR supported by DfEE and CIHE.

Hegarty-Hazel, E. (1990). *The student laboratory and the science curriculum* . London: Routledge.

Heller, P. & Mark, H. (1992). Teaching problem solving through cooperative grouping, part 2, designing problems and structuring groups. *American Journal of physics*, *60*, 637–644.

Hodson, D. (1986). The nature of scientific observation. *School Science Review, 68*, 17–28.

Hodson, D. (1996). Laboratory work as scientific method: three decades of confusion and distortion. *Journal of Curriculum Studies*, *82*(2), 115–135.

Howe, N. & Strauss, W. (2003). Millennials go to college. *American Association of Collegiate Registrars and Life Course Associates*, 70–84.

Hugh, C. (1911). *Encyclopædia britannica* (11th) (C. Hugh, Ed.). Cambridge University Press.

Igelsrud, D. & Leonard, W. H. (1988). Labs: what research says about biology lab instruction. *The American biology teacher*, *50*(5), 303–306.

Johnstone, A. H. (1984). New stars for the teachers to steer by. *Journal of Chemical Education*, *61*(10), 847–849.

Johnstone, A. H. (1991). Why science is difficult to learn? things are seldom what they seem, *Journal of Computer Assisted Learning*, *7*, 75–83.

Johnstone, A. H. (1993). Development of chemistry teaching: a changing response to changing demand. *Journal of Chemistry Education*, *70*(9), 701–705.

Johnstone, A. H. (1997). Chemistry teaching - science or alchemy? *Journal of Chemical Education*, *74*(3), 262–268.

Johnstone, A. H. (1999). The nature of chemistry. *Education in Chemistry*, *36*(2), 45–48.

Johnstone, A. H. & El-Banna, H. (1986). Capacities, demands and processes: a predictive model for science education. *Education in Chemistry*, *23*(3), 80–84.

Johnstone, A. H. & El-Banna, H. (1989). Understanding learning difficulties - a predictive research model. *Studies in Higher Education*, *14*(2).

Johnstone, A. H., Hogg, W. & Raja, S. (1997). How long is a chain?reasoning in science.. *School Science Review*, *78*(285), 73–77.

Johnstone, A. H., Sleet, R. & Vianna, J. F. (1994). An information processing model of learning: its application to an undergraduate laboratory couse. *Chemistry Studies in Higher Education*, *19*(1), 77–87.

Johnstone, A. (1988). *Some messages for teachers and examiners, an information processing model." learning difficulties and teaching strategies in secondary school science and mathematics,* Free University Press, Amsterdam.

Johnstone, A. & Letton, K. (1990). Investigation undergraduate laboratory work. *Education in Chemistry*, *27*, 9–11.

Johnstone, A. & Letton, K. (1991). Practical measuresfor practica lwork. *Educationin chemistry*, *28*(3), 81–83.

Johnstone, A. & Al-Shuaili. (2001). Learning in the laboratory: some thoughts from the literature. *University Chemistry Education*, *5*, 42–51.

Johnstone, A., Watt, A. & Zaman, T. U. (1998). The students' attitude and cognitive change to a physics laboratory. *physics education*, *33*(1), 22–29.

Johnstone, A. & Wood, C. (1977). Practical work in its own right. *Education in Chemistry*, *14*, 11–12.

Johnstone, A. H. (2000). Teaching of chemistry - logical or psychological. *Chemistry Education Research and Practice in Europe*, *1*(1), 9–15.

Johnstone, A. H. & Wham, A. J. (1982). The demands of practical work. *Education in Chemistry*, *19*(3), 71–73.

Keller, J. (1983). Motivational design of instruction i|n instructional dessign. In R. C.M. (Ed.), *Theories and models:an overview of there current statues* (pp. 383–433). Hillsddale: NJ ;lawrence Erlbaun Assosiats.

Kempa, R. F. & Nicholls, C. E. (1983). Problem-solving ability and cognitive structure an exploratory investigation. *European Journal of Science Education*, *5*(2), 171–184.

Kempa, R. F. & Ward, J. E. (1988). Observational thresholds in school chemistry. *InternationalJournal of Science Education*, *10*(3), 275–284.

Kerber, R. (1988). Elephantiasis of the textbook. *Journal of Chemical Education*, *65*, 719–7 20.

Kirschner, P., Sweller, J. & Clark, R. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2).

Kirschner, P. & Meester, M. (1988). The laboratory in higher science education, problems, premises and objectives. *Higher Education*, *17*, 81–98.

Kyle, W., Penick, J. & Shymansky, J. (1979). Assessing and analyzing the performance of students in college science laboratories. *Journal of research in Science Teaching. 16*(6), 545–551.

Lagowski, J. (1990). Entry-level science courses: the weak link. *Journal of chemical Education*, *67*(7), 541.

Larochelle, M., Madine, B. & Garrison, J. (1998). *Constructivism and education.* New York: Cambridge University Press.

Laws, P. (1996). Undergraduate science education. *A Review of Research,Studies in Science Education*, *28*(1).

Letton, K. M. (1987). *A study of the factors influencing the efficiency of learning in a undergraduate chemistry laboratory* (Master's thesis, Jordanhill College of Education, Glasgow, Scotland).

Light, G., Cox, R. & Calkins, S. (2001). *Learning and teaching in higher education: the reflective professional* (2st ed). London: SAGE, London.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, *140*, 5–53.

Lycnh, P. & Ndyetabura, V. (1983). Practical work in schools: an examination of teachers' stated aims and the influence of practical work according to students, *Journal of Research in Science Teaching*, *20*(7), 663–671.

Mackenzie, A., Johnstone, A. & Brown, R. (2003). Learning from problem based learning, *University Chemistry Education*, *7*(1), 13–24.

Marton, F. & Säljö, R. (1992). *Learning to teach in higher education.* Routledge.

Maxwell, J. P., Masters, R. & Eves, F. (2003). The role of working memory in motor learning and performance. *Consciousness and Cognition*, *12*(3), 376–402.

McKelvy, G. (2000). Preparing for the chemistry laboratory: an internet presentation and assessment tool. *University Chemistry Education*, *4*, 46–49.

Meester, M. & Maskill, R. (1994). *Second yearpractical classes in undergraduate chemistry courses in england and wales.* London: The Royal Society of Chemistry.

Meester, M. & Maskill, R. (1995). First year chemistry practical s at university in england and wales: aims and the scientific level of the experiments. *International Journal of Science Education*, *17*, 575–588.

Menzie, J. C. (1970). The lost arts of experimentational investigation. *American Journal of physics*, *38*, 1121–1127.

Miller, G. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information, , psychological review. *Psychological Review*, *63*(2), 81–87.

Miller, P. H. (1993). *Theories of developmental psychology.* New York: W.H. Freeman and Company.

Moreira, M. A. (1980). A non-traditional approach to the evaluation of laboratory instruction in general physics course,uropean, *Journal of Science Education*, *2*(4), 441–448.

Morrell, J. B. (1972). The chemist breeders, *the research school of liebig and Thomas Thomson, AMBIX, 19*(1), 1–47.

National Committee for Universities. (2010). *Anual report.* General Committee of Higher Education.

Niaz, M. (1987). Relationship between m-space of students and m- demand of different items of general chemistery and its interpretation based upon the neo-piagetian theory of pascual-leone. *Journal of chemical Education*, *6*(64), 502–505.

Nolen-Hoeksema, S., Fredrickson, B. L., Loftus, G. & Wagenaar, W. (2009). *Atkinson & hilgard's introduction to psychology* (N.-H. 09, Ed.). Stamford, USA: Cengage Learning.

Novak, J. D. (1978). An alternative to piagetian psychology for science and mathematics education. *Studies in Science Education*, *5*, 1–30.

Oraif, F. (2007). *An exploration of confidence related to formal learning in saudi arabia* (Doctoral dissertation, The Unoiversity of Glasgow).

Osborne, J., Driver, R. & Simon, S. (1998). Attitudes to science: issue and concerns. *School Science Review*, *3*(78(288)), 27–33.

Osgood, C., Suci, C. & Tannenbaum, P. (1957). *The measurement of meaning, urbana,* USA: University of Illinois Press.

Paivo, A., Clark, J. & Lamber, W. (1988). Bilingual dual-coding theory and semantic repetitione effect on recall. *Journal of Experimental Psychology.: Learning Memory, and Cognition*, *14*, 163–172.

Perry, W. G. (1999). *Forms of ethical and intellectual development in the college years: a scheme.* San Francisco: Jossey- Bass.

Phillips, M. (1981). Early history of physics laboratories for students at the college level. *American Journal of physics*, *49*, 522–527.

Piaget, J. (1950). *The psychology of intelligence.* London, UK: Routledge & Paul.

Pickering, M. (1989). Choosing to cookbook: student choices of laboratory strateg. *Journal of Chemical Education*, *66*(10), 845.

Ramsden, P. (1992). *Learning to teach in higher education.* London, UK: Routledge.

Raths, L., S.Wassermann, A. J. & Rothstein, A. (1986). *Teaching of thinking: theories,strategies and activities for the classroom.* New York: Teacher College,Columbia University, Redish, E. F. (1994). Implications of cognitive studies for teaching physics. *American Journal of Physics*, *62*(9), 769–803.

Reid, N. (2003). *Getting started in pedagogical research in higher education,* Hull: Higher Education Academy Physical Sciences.

Reid, N. (2009). Working memory and science education, *Research in Science and Technological Education, 27*(2), 245–250.

Reid, N. (2011). Attitude research in science education. In I. Saleh & M. Khine (Eds.), *Attitude research in science education* (2, pp. 3–44). Charlotte NC: Information Age Publishing Inc.

Reid, N. & Shah, I. (2007). The role of laboratory work in university chemistry. *Chemistry Education Research and Practice*, *8*(2), 172–185.

Reid, N. & Skryabina, E. (2002). Attitudes towards physics. *Research in Science and Technological Education*, *20*(1), 67–81.

Reid, N. & Yang, M. (2002). Open-ended problem solving in school chemistry : a preliminary investigation. *International Journal Science Education*, *24*(12), 1313–1332.

Reid, N. (2006). Thoughts on attitude measurement. *Research in Science and Technological Education*, *24*(1), 3–27.

Reid, N. (2008). A scientific approach to the teaching of chemistry. *Chemistry Education Research and Practice*, *9*(1), 51–59.

Robinson, K. (2010). *Out of our minds - what is wrong with education?*

Rowell, J. & Dawson, C. (1988). Whats' in a solution? a look at logic and belief in problem solving. *Research in Science Education*, *18*, 143–151.

Salem, M. (2000). *Alfezia altjrebia*. Egypt: Maktabt Maser.

Schneider, W. & Shiffrin, R. M. (1977). Controlled and automatic human information processing (i): detection, search and attention. *Psychological Review*, *84*, 1–66.

Scottish Qualification Authority (SQA). (1962 to 2012). *Annual reports.* Scottish Examination Board.

Selepeng, B. (1995). *Teaching and learning science in a second language.* (Master's thesis, Centre for Science Education, University of Glasgow).

Selepeng, D. (2000). *An investigation of intellectual growth in undergraduate biology students using the perry scheme* (Doctoral dissertation, University of Glasgow).

Serumola, L. (2003). *Astudy of scientific thinking with youngadolescents* (Doctoral dissertation, University of Glasgow).

Shah, I. (2004). *Making university laboratory work in chemistry more effective* (Doctoral dissertation, University of Glasgow, Glasgow).

Shah, I., Riffat, O. & Reid, N. (2007). Students perceptions of laboratory work in chemistry at school and university in pakistan . *Journal of Science Education*, *8*(21), 75–78.

Shepherd, R. (1979). *Individual practical work in the teaching of physics in england: a study of origins and rationale* (Master's thesis, University of Leeds).

Shymansky, J. A. & Penick, J. E. (1979). Use of systematic observations to improve college science laboratory instruction. *Science Education*, *63*(2), 195–203.

Sirhan, G., Gray, C., Johnstone, A. & Reid, N. (1999). Preparing the mind of the learner. *University Chemistry Education, 3*(2), 43–46.

Sirhan, G. & Reid, N. (2000). Preparing the mind of the learner - part 2. *University Chemistry Education*, *5*, 52–58.

Skemp, R. R. (1976). Relational understanding and instrumental understanding. *Mathematics Teaching*, *77*, 55–65.

Skemp, R. R. (1987). *The psychology of learning mathematics.* New York, USA: Lawrence Erlbaum Associates Publishers.

Skryabina, E. (2000). *Students attitude to learning physics at school and university levels in scotland.* (Doctoral dissertation, University of Glasgow).

Slavin, R. E. (2000). *Educational psychology* (6th). Boston, USA: Allyn & Bacon.

Sneddon, P., Slaughter, K. & Reid, N. (2009). Perceptions, views and opinions of university students about physics learning during practical work at school, *European Journal of Physics*, *30(1)*, 1119–1129.

Snelbecker, G. E. (1974). *Learning theory, instructional theory, and psychoeducational design.* New York: McGraw-Hill.

Social Science Statistics. (2013). T-test calculator for 2 independent means. Retrieved March 3, 2013, from http://www.socscistatistics.com/tests/studentttest/Default.aspx

Solomon, J. (1980). *Teaching children in the laboratory.* Croom Helm.

Solso, R. L. (1998). *Cognitive psychology* (5th). Boston, USA: Allyn & Bacon.

Squire, L., Knowlton, B. & Musen, G. (1993). The structure and organisation of memory. *Annual Review of Psychology*, *44*, 453–495.

Sutherland, P. A. (1982). An expansion of peel's describer - explainer stage theory. *Educational Review*, *34*(1), 69–76.

Sutherland, P. A. (1992). *Cognitive development today: piaget and his critics.* London, UK: Sage Publications Ltd.

Sweller, J. (1988). Cognitive load during problem solving: effects on learning, *Cognitive Science*, *12*, 257–285.

Tan, C. (1990). Some factors influencing students performance in laboratory experimental work in physiology with implication for curriculum deliberation and instructional desige. *Eigher Education*, *19*, 473–479.

Tóth, Z. (2007). Mapping students' knowledge structure in understanding density, mass percent, molar mass, molar volume and their application in calculations by the use of the knowledge space theory. *Chemistry Educa tion Research and Practice*, *8*(4), 376–389.

Tulving, E. (1993). What is episodic memory? current directions in, *Psychological Science*, *2*, 67–70.

Tuovinen, J. & Sweller, J. (1999). Acomparison of cognitive load associated with discovery learning and working examples. *Journal of Educational psychology*, *91*, 334–341.

Vygotsky, L. (1962). *Thought and language.* MIT Press.

Vygotsky, L. (1986). *Thought and language* (A. Kozulin, Ed. & Trans.). Cambridge: MIT Press.

Wadsworth, B. J. (1984). *Piagets theory of cognitive and affective development.* New York: Longman.

Wadsworth, B. J. (1989). *Piaget's theory of cognitive and affective development* (4th ed.). Newyork: Longman.

Wiersma, W. (1995). *Research methods in education: an introduction* (6th ed.). Boston: Allyn and Bacon.

Wills, E. (1974). Comparison of students performances tested by continuous assessment and by a final examination. In D. Billing & J. Parsonage (Eds.), *Research into tertiary science education.* London: Society for Research into Higher Education.

Wood, C. & Sleet, R. (1993). *Creative problem solving in chemistry.* London: The Royal Society of Chemistry.

Woolnough, B. (1994). "why students' choose physics, or reject it. *Physics Education*, *29*, 368–374.

Young, B. (1979). *Teaching primary science,* Harlow, Longman Group.

Zaman, T., Johnstone, A. & Watt, A. (1998). The students' attitude, and cognition change, to a physics laboratory. *Physics Education*, *33*, 22–29.

Zoller, U. (1993). Lecture and learning: are they compatible? maybe for lcos, unlikely for hocs. *Journal of a Chemical Education*, *70*(3), 195–197.

Zoller, U. (2000). Teaching tomorrow's college science courses: are we getting it right? *Journal of College Science Teaching*, *29*(6), 409–415.

Appendices

Appendix A

First Stage Appendix

A.1 Laboratory Work in Physics (at school)

A.1.1 Questionnaire

Student no:………………

Q1. What is your gender?

Female ☐ Male ☐

Q2. What degree do you intend to study at university?

Physics ☐ Mathematics ☐ Computer science ☐ Statistics ☐

Q3. Think about your experiences in practical Physics work.

(Tick the box which best reflects your opinion).

	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
(a)	I prefer to have written instructions for experiments.	☐	☐	☐	☐	☐
(b)	Practical work helps my understanding of Physics topics.	☐	☐	☐	☐	☐
(c)	Discussions in the laboratory enhance my understanding of the subject.	☐	☐	☐	☐	☐
(d)	I felt confident in carrying out the experiments in Physics.	☐	☐	☐	☐	☐
(e)	The experimental procedure was clearly explained in the instructions given.	☐	☐	☐	☐	☐
(f)	I was so confused in the laboratory that I ended up following the instructions without understanding what I was doing.	☐	☐	☐	☐	☐
(g)	There was good linkage between experiments and the relevant theory.	☐	☐	☐	☐	☐

Here is a way to describe a racing car.

quick	☑	☐	☐	☐	☐	☐	slow
important	☐	☐	☑	☐	☐	☐	unimportant
safe	☐	☐	☐	☐	☑	☐	dangerous

The positions of the ticks between the word pairs show that you consider it as very quick, slightly more important than unimportant and quite dangerous.

Q4. What are your opinions about your school laboratory experiences in Physics?

(Tick ONE box on each line).

Useful	☐	☐	☐	☐	☐	☐	Useless
Not helpful	☐	☐	☐	☐	☐	☐	Helpful
Understandable	☐	☐	☐	☐	☐	☐	Not understandable
Boring	☐	☐	☐	☐	☐	☐	Interesting
The best part of physics	☐	☐	☐	☐	☐	☐	The worst part of physics
Not enjoyable	☐	☐	☐	☐	☐	☐	Enjoyable

Q5. Here are several reasons why laboratory work is an integral part of Physics course.

1. Physics is a practical subject
2. Experiments illustrate theory for me
3. Laboratory work allows me to test out ideas
4. Experiments assist me to planning and organise
5. New discoveries are made by means of experiments
6. Experimental skills can be gained in the laboratory
7. Experimental work allows me to think about Physics
8. Experimental work makes Physics more enjoyable for me

Pick the three which you consider to be integral and rank them in descending order of importance in the boxes below.

First	Second	Third
☐	☐	☐

Q6. In what ways do you think university practical work will differ this year from the practical work you experienced at school? (Choose up to three answers)

- Use of more complicated equipment. ( )
- Use of modern equipment. ( )
- I will get less guidance than at school. ( )
- I will have more time for each experiment. ( )
- I will do the experiments myself instead of watching them being done. ( )
- I will have more choice in the experiments I do. ( )

Q7. Are you looking forward to the practical work this year?

Very much ☐ ☐ ☐ ☐ ☐ ☐ Not at all

Q8. Which of the following would best describe your practical physics experience at school?

(a)	I carried out some of my experiments by myself.	☐
(b)	Most of my experiments were done as computer-based simulations.	☐
(c)	My teacher carried out most of my experiments as demonstrations.	☐
(d)	I did most of my experiments myself, either alone or in groups.	☐

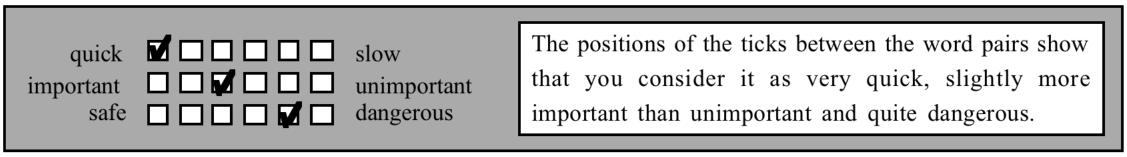
A.1.2 Data from first Questionnaire 'School Sample'

Responses below for question three and four.

Q3. Student experiences in practical Physics work:

		%				
	N	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
(a)	*I prefer to have written instructions for experiments*					
	150	32	38	8	13	9
(b)	*Practical work helps my understanding of Physics topics*					
	150	21	17	7	30	25
(c)	*Discussions in the laboratory enhance my understanding of the subject*					
	150	37	28	10	14	11
(d)	*I felt confident in carrying out the experiments in Physics.*					
	150	20	24	15	19	22
(e)	*The experimental procedure was clearly explained in the instructions given.*					
	150	21	25	11	21	22
(f)	*I was so confused in the laboratory that I ended up following the instructions without understanding what I was doing.*					
	150	33	32	9	13	13
(g)	*There was good linkage between experiments and the relevant theory.*					
	150	34	34	11	14	7

The description below was used by students to express their opinions about school laboratory.



Q4. Students opinions about school laboratory experiences in Physics

N		%						
150	*Useful*	20	21	15	17	13	14	*Not useful*
150	*Helpful*	23	24	13	10	15	15	*Not helpful*
150	*Understandable*	18	22	11	11	20	18	*Not understandable*
150	*Interesting*	22	22	13	14	15	14	*Boring*
150	*The best part of Physics*	14	15	14	15	21	21	*The worst part of Physics*
150	*Enjoyable*	26	18	11	12	16	17	*Not enjoyable*

A.2 Laboratory Work in Physics (at University)

A.2.1 Questionnaire

Student no:………………

Q1. What is your gender?

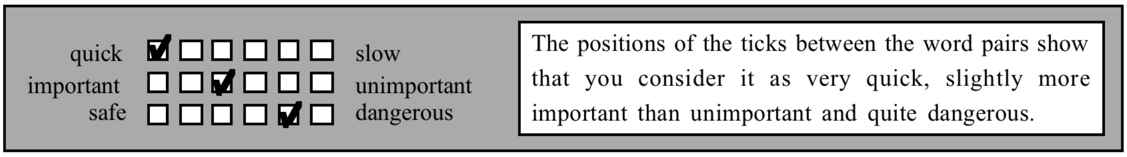
Female ☐ Male ☐

Q2. Think about your experiences in practical Physics work.

(Tick the box which best reflects your opinion).

	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
(a)	I prefer to have written instructions for experiments.	☐	☐	☐	☐	☐
(b)	Practical work helps my understanding of Physics topics.	☐	☐	☐	☐	☐
(c)	Discussions in the laboratory enhance my understanding of the subject.	☐	☐	☐	☐	☐
(d)	I felt confident in carrying out the experiments in Physics.	☐	☐	☐	☐	☐
(e)	The experimental procedure was clearly explained in the instructions given.	☐	☐	☐	☐	☐
(f)	I was so confused in the laboratory that I ended up following the instructions without understanding what I was doing.	☐	☐	☐	☐	☐
(g)	There was good linkage between experiments and the relevant theory.	☐	☐	☐	☐	☐

Here is a way to describe a racing car.



Q3. What are your opinions about your school laboratory experiences in Physics?

(Tick ONE box on each line).

Useful	☐	☐	☐	☐	☐	☐	Useless
Not helpful	☐	☐	☐	☐	☐	☐	Helpful
Understandable	☐	☐	☐	☐	☐	☐	Not understandable
Boring	☐	☐	☐	☐	☐	☐	Interesting
The best part of physics	☐	☐	☐	☐	☐	☐	The worst part of physics
Not enjoyable	☐	☐	☐	☐	☐	☐	Enjoyable

Q4. Here are several reasons why laboratory work is an integral part of Physics course.

1. Physics is a practical subject
2. Experiments illustrate theory for me
3. Laboratory work allows me to test out ideas
4. Experiments assist me to planning and organise
5. New discoveries are made by means of experiments
6. Experimental skills can be gained in the laboratory
7. Experimental work allows me to think about Physics
8. Experimental work makes Physics more enjoyable for me

Pick the three which you consider to be integral and rank them in descending order of importance in the boxes below.

First	Second	Third
☐	☐	☐

Q5. Please answer the following questions in terms of your experience in this semester only. Think back over the experiments which you have completed during this semester.

(a) Which experiment did you find most useful or enjoyable?

(b) What was it about that experiment that made it particularly useful or enjoyable?

(c) Did you find the experiment easy or challenging?

(d) What did it teach you?

(e) List any skills which improved as a result of doing the experiment.

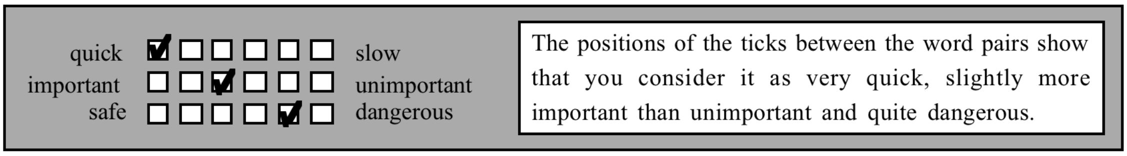
A.2.2 Data from Second Questionnaire ‘University Sample’

Responses below for question two and three.

Q2. Student experiences in practical Physics work:

		%				
	N	S. Agree	Agree	Not Sure	Disagree	S. Disagree
(a)	*I prefer to have written instructions for experiments*					
	150	35	38	7	12	8
(b)	*Laboratory work helps my understanding of Physics topics*					
	150	19	15	11	33	22
(c)	*Discussions in the laboratory enhance my understanding of the subject*					
	150	40	30	8	11	11
(d)	*I felt confident in carrying out the experiments in Physics.*					
	150	22	30	12	16	20
(e)	*The experimental procedure was clearly explained in the instructions given.*					
	150	15	16	14	30	25
(f)	*I was so confused in the laboratory that I ended up following the instructions without understanding what I was doing.*					
	150	30	33	12	13	12
(g)	*There was good linkage between experiments and the relevant theory.*					
	150	18	18	15	24	25

The description below was used by students to express their opinions about school laboratory.



Q3. Students opinions about school laboratory experiences in Physics

N		%						
150	*Useful*	20	21	14	17	13	15	*Not useful*
150	*Helpful*	22	23	14	11	15	15	*Not helpful*
150	*Understandable*	21	17	10	12	20	20	*Not understandable*
150	*Interesting*	22	22	13	14	15	14	*Boring*
150	*The best part of Physics*	13	14	14	15	22	22	*The worst part of Physics*
150	*Enjoyable*	33	23	11	10	12	11	*Not enjoyable*

Appendix B

Second Stage Appendix

B.1 Experiment 1: Determination of the refractive index of a glass prism using a spectrometer

B.1.1 Pre-Lab

You should read the Pre-Lab sheet before you come to the lab. The staff in the lab will check if you did or not.

What should I know before I begin?

You should know:

- You should be familiar with the phenomena of refraction.
- You should be familiar with how to set up and adjust the spectrometer.
- You should be sufficiently familiar with how to use spectrometer.
- You should know what the angle of deviation means and it's relation with the angle of incident.

What does a spectrometer do?

You will use a spectrometer as an instrument for determining the refractive index of a glass prism. The simple spectrometer consists of three parts:

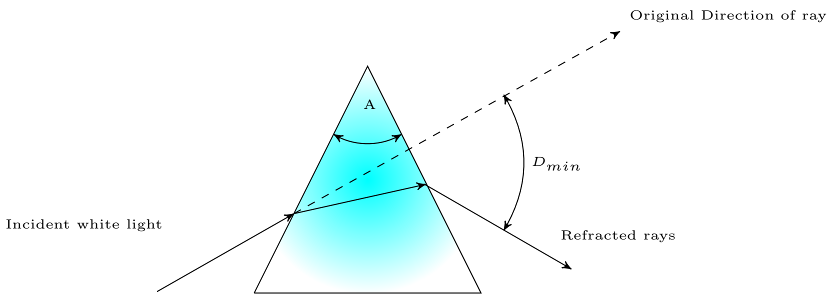
- The collimator which provides a parallel beam of light from the source. It consists of a tube with an achromatic lens at one end and an adjustable slit at the other.
- The prism which disperses the light received from the collimator.
- The telescope which receives the dispersed light from the prism. It is provided with an eyepiece fitted with cross-hairs.

Why use it in this practical?

A spectrometer is ideal for the objective of this experiment.

What is the experiment about?

- You will determine the refractive index of a glass prism a using spectrometer.



What will I be doing?

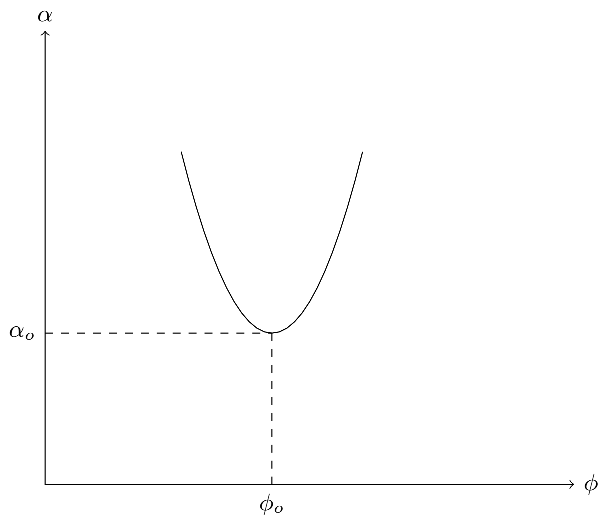
Read the description in the manual; also see the book (Alfezia Altjrebia, “Practical physics” by Mohamed Salem, (2000) الفيزياء التجريبية لمحمد سالم) After you do the above please answer these questions:

1. Why does the phenomena of refraction occur?
2. Define the term refractive index.
3. Define the angle of deviation.

B.1.2 Post-lab

Answer these questions :

1. Suppose that the angle of incidence of a laser beam in water and heading towards air is adjusted to 50°. Given the refractive index of water is 1.33; can you calculate the angle of refraction? Explain your result.
2. When violet and red colour come out from prism which one has greater deviation angle, and why?
3. Why does the light which comes out from the triangular prism disperse into component colour?
4. In the diagram below: the y-axis represents the angles of deviation (α) in the triangular prism, the x-axis represents the angle of incident (ϕ). Explain this diagram and what does (α_o) mean?



B.1.3 Data from Questionnaire used after First Experiment

See D.1 for the original question. Responses for question one, part one:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (a)	*This experiment was easy to do*					
With Pre-lab	45	27	42	0	20	11
Without Pre-lab	50	20	22	0	30	28
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*					
With Pre-lab	45	36	37	0	22	5
Without Pre-lab	50	24	18	0	32	26
Q1 (c)	*Preparation for the lab was not very helpful in following the experimental procedure*					
With Pre-lab	45	9	15	7	38	31
Without Pre-lab	50	28	30	10	18	14
Q1 (d)	*Having done this experiment I now find the topic more interesting*					
With Pre-lab	45	36	31	13	20	0
Without Pre-lab	50	20	18	10	38	14
Q1 (e)	*I found this experiment was difficult*					
With Pre-lab	45	11	20	0	42	27
Without Pre-lab	50	30	28	0	20	22
Q1 (f)	*When I started this experiment, I didn't know what its purpose was*					
With Pre-lab	45	7	20	0	37	36
Without Pre-lab	50	28	30	0	20	22
Q1 (g)	*Apparatus used in this experiment was difficult to handle*					
With Pre-lab	45	9	15	3	46	27
Without Pre-lab	50	32	24	16	10	18
Q1 (h)	*Preparation for this experiment not contributed to my understanding of the course*					
With Pre-lab	45	7	20	33	33	7
Without Pre-lab	50	28	18	18	20	16
Q1 (i)	*I could not do a similar experiment on my own without further instruction*					
With Pre-lab	45	25	42	20	7	7
Without Pre-lab	50	34	38	12	8	8
Q1 (j)	*My preparation for this experiment made me not interested in the subject.*					
With Pre-lab	45	2	18	13	29	38
Without Pre-lab	50	16	36	10	18	20

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question one, part two:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*					
With Pre-lab	45	28	40	5	11	16
Without Pre-lab	50	10	18	12	30	30
Q1 (l)	*It was easy to follow the laboratory manual*					
With Pre-lab	45	25	44	0	29	2
Without Pre-lab	50	10	24	0	36	30
Q1 (m)	*For this experiment it was easy to use the apparatus*					
With Pre-lab	45	29	44	3	15	9
Without Pre-lab	50	16	12	16	26	30
Q1 (n)	*I successfully completed this experiment within the prescribed time*					
With Pre-lab	45	42	33	0	16	9
Without Pre-lab	50	28	32	0	16	24
Q1 (o)	*I need more information on how to prepare for this experiment*					
With Pre-lab	45	16	11	5	42	26
Without Pre-lab	50	32	28	12	18	10
Q1 (p)	*Experimental procedure was more clear due to my preparation*					
With Pre-lab	45	11	57	7	20	5
Without Pre-lab	50	10	16	16	32	26
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*					
With Pre-lab	45	27	22	31	11	9
Without Pre-lab	50	16	14	24	24	26
Q1 (r)	*The experiment helped me to understand some of the course work*					
With Pre-lab	45	14	53	11	15	7
Without Pre-lab	50	14	22	12	22	30
Q1 (s)	*The procedure was not clearly explained in the lab manual*					
With Pre-lab	45	3	28	0	18	51
Without Pre-lab	50	24	38	10	16	12
Q1 (t)	*Not enough time was given to complete the experiment*					
With Pre-lab	45	9	22	0	18	51
Without Pre-lab	50	28	38	0	20	14

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question two:

Group	**N**		**%**						
With Pre-lab	45	*Useful*	42	27	11	13	4	3	*Not useful*
Without Pre-lab	50		22	10	10	0	30	28	
With Pre-lab	45	*Helpful*	27	37	13	18	3	2	*Not helpful*
Without Pre-lab	50		28	14	0	20	20	18	
With Pre-lab	45	*Meaningful*	20	27	24	16	13	0	*Not meaningful*
Without Pre-lab	50		14	20	20	20	16	10	
With Pre-lab	45	*Understandable*	31	31	16	2	18	2	*Not understandable*
Without Pre-lab	50		14	20	20	20	16	10	
With Pre-lab	45	*Satisfying*	0	48	13	9	18	12	*Not satisfying*
Without Pre-lab	50		12	16	10	16	16	30	
With Pre-lab	45	*Interesting*	33	36	11	4	11	5	*Boring*
Without Pre-lab	50		16	22	24	10	14	14	
With Pre-lab	45	*Well-organised*	0	31	29	29	9	2	*Not well-organised*
Without Pre-lab	50		16	12	14	20	18	20	

B.2 Experiment 2: Determination of the wavelength of sodium light using Newton's Rings

B.2.1 Pre-Lab

You should read the Pre-Lab sheet before you come to the lab. The staff in the lab will check if you did or not.

What should I know before I begin?

- You should have knowledge about interference.
- You should know how the travelling microscope works, (see Alfezia Altjrebia, "Practical physics" by Mohamed Salem, (2000) الفيزياء التجريبية لمحمد سالم, page 315).
- You should know the accepted value of the wave length of sodium light
- You should know information about the nature of sodium light.
- You should know about the plane convex lens.

After you know the above please ask yourself these questions:

- What is the definition of interference?
- What are the types of interference, and what are the conditions for the interference phenomena to occur?
- What does wavelength mean?

What apparatuses should I use?

You are going to use these apparatuses: Travelling microscope, convex lens, plane convex lens, plane glass plate (optically flat), sodium light source and magnifying torch.

What will I measure and how?

- You will measure the wave length of sodium light.
- Read the instruction sheet, see also the book (Alfezia Altjrebia, “Practical physics” by Mohamed Salem, (2000) الفيزياء التجريبية لمحمد سالم)

Why are Newton rings formed?

Newton’s rings are formed due to interference between the light waves reflected from the top and bottom surfaces of the air film formed between the lens and glass sheet. The phenomenon of the formation of Newton’s Rings can be explained on the basis of wave theory of light:

- An air film of varying thickness is formed between the lens and the glass sheet.
- When a light ray is incident on the upper surface of the lens, it is reflected as well as refracted.
- When the refracted ray strikes the glass sheet, it undergoes a phase change of $180°$ on reflection.
- Interference occurs between the waves which interfere constructively if path difference between them is $(m + 1/2)\,\lambda$ and destructively if path difference between them is $m\,\lambda$ producing alternate bright and dark rings (Halliday & Resnick, 1988)

B.2.2 Post-Lab

Please answer these questions:

1. Could you explain how interference occurs in this experiment (Newton's ring)?
2. Is it possible to determine the refractive index of the liquid by this experiment?
3. Do you think there will be a difference if you replace the glass plate with a plane mirror?
4. Can you use a point source instead of an extended source in the experiment of Newton's ring? And why?

B.2.3 Data from Questionnaire used after Second Experiment

See D.1 for the original question. Responses for question one, part one:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (a)	*This experiment was easy to do*					
With Pre-lab	45	31	40	0	14	15
Without Pre-lab	50	22	16	0	30	32
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*					
With Pre-lab	45	31	40	4	20	5
Without Pre-lab	50	16	16	10	32	26
Q1 (c)	*Preparation for the lab was not very helpful in following the experimental procedure*					
With Pre-lab	45	9	22	0	49	20
Without Pre-lab	50	28	30	0	22	20
Q1 (d)	*Having done this experiment I now find the topic more interesting*					
With Pre-lab	45	33	36	0	17	14
Without Pre-lab	50	6	18	14	40	22
Q1 (e)	*I found this experiment was difficult*					
With Pre-lab	45	15	14	0	38	33
Without Pre-lab	50	34	28	0	20	18
Q1 (f)	*When I started this experiment, I didn't know what its purpose was*					
With Pre-lab	45	7	20	4	40	29
Without Pre-lab	50	28	30	8	18	16
Q1 (g)	*Apparatus used in this experiment was difficult to handle*					
With Pre-lab	45	9	20	0	27	44
Without Pre-lab	50	34	28	10	14	14
Q1 (h)	*Preparation for this experiment not contributed to my understanding of the course*					
With Pre-lab	45	5	15	9	51	20
Without Pre-lab	50	10	10	20	32	28
Q1 (i)	*I could not do a similar experiment on my own without further instruction*					
With Pre-lab	45	9	2	22	44	23
Without Pre-lab	50	22	14	34	12	18
Q1 (j)	*My preparation for this experiment made me not interested in the subject.*					
With Pre-lab	45	17	13	2	35	33
Without Pre-lab	50	24	38	14	16	8

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question one, part two:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*					
With Pre-lab	45	36	38	9	9	9
Without Pre-lab	50	14	16	16	30	24
Q1 (l)	*It was easy to follow the laboratory manual*					
With Pre-lab	45	27	20	20	20	13
Without Pre-lab	50	10	18	22	24	26
Q1 (m)	*For this experiment it was easy to use the apparatus*					
With Pre-lab	45	44	27	0	18	11
Without Pre-lab	50	14	14	10	36	26
Q1 (n)	*I successfully completed this experiment within the prescribed time*					
With Pre-lab	45	66	5	0	24	5
Without Pre-lab	50	22	16	0	30	32
Q1 (o)	*I need more information on how to prepare for this experiment*					
With Pre-lab	45	9	9	9	36	38
Without Pre-lab	50	24	32	16	14	14
Q1 (p)	*Experimental procedure was more clear due to my preparation*					
With Pre-lab	45	18	51	0	20	11
Without Pre-lab	50	20	22	0	32	26
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*					
With Pre-lab	45	21	46	22	0	11
Without Pre-lab	50	18	12	34	16	20
Q1 (r)	*The experiment helped me to understand some of the course work*					
With Pre-lab	45	20	51	7	15	7
Without Pre-lab	50	10	10	20	32	28
Q1 (s)	*The procedure was not clearly explained in the lab manual*					
With Pre-lab	45	15	18	20	27	20
Without Pre-lab	50	24	24	22	20	10
Q1 (t)	*Not enough time was given to complete the experiment*					
With Pre-lab	45	5	24	0	7	64
Without Pre-lab	50	30	32	0	20	18

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question two:

Group	**N**		%						
With Pre-lab	45	*Useful*	51	24	9	7	7	2	*Not useful*
Without Pre-lab	50		24	22	14	16	14	10	
With Pre-lab	45	*Helpful*	20	53	7	9	11	0	*Not helpful*
Without Pre-lab	50		16	18	10	22	18	16	
With Pre-lab	45	*Meaningful*	7	49	20	11	11	2	*Not meaningful*
Without Pre-lab	50		18	16	12	20	22	12	
With Pre-lab	45	*Understandable*	51	18	4	9	13	5	*Not understandable*
Without Pre-lab	50		10	16	10	14	26	24	
With Pre-lab	45	*Satisfying*	5	33	33	16	11	2	*Not satisfying*
Without Pre-lab	50		14	18	10	20	22	16	
With Pre-lab	45	*Interesting*	11	38	18	13	16	4	*Boring*
Without Pre-lab	50		20	16	18	14	20	12	
With Pre-lab	45	*Well-organised*	0	24	40	20	13	3	*Not well-organised*
Without Pre-lab	50		26	20	10	10	18	16	

B.3 Experiment 3: Determination of wavelength of light from the helium neon laser

B.3.1 Pre-Lab

You should read the Pre-Lab sheet before you come to the lab. The staff in the laboratory are going to check if you did or not.

What should I know before I begin?

- You should be familiar with the principles of the operation of a laser.
- The characteristics of laser light which make it suitable for this experiment.
- You should be sufficiently familiar with the ideas of diffraction interference to understand the experiment.
- Remove watches bracelets, rings and other jewelry that might reflect the laser light.
- Under any circumstances:
    1. Do not look directly into the laser beam at any time.
    2. Do not shine the laser towards anyone.
    3. Do not shine reflected laser light towards anyone.

What does laser do?

The unique characteristics of light produced by laser make it suitable for many applications, for example:

- Precision length measurement.
- Medical.
- Drilling.
- Tracking.
- Welding.

- Velocity measurement.
- Cutting.

Why measure laser wavelength in this practical?

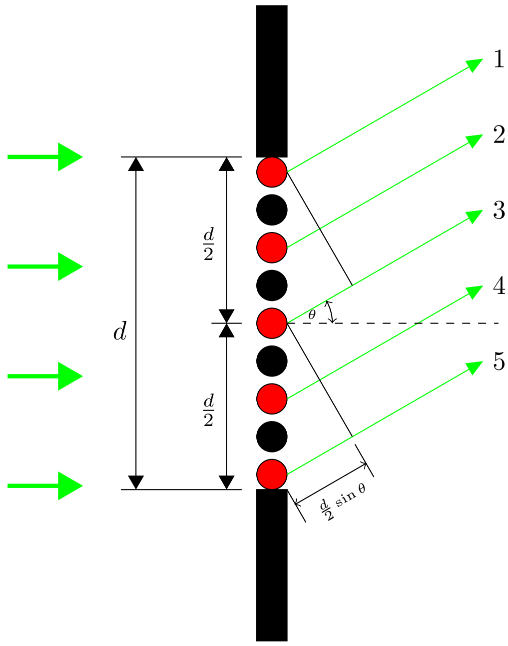
Laser light contains only one wavelength which results in very sharp diffraction patterns. Other sources emit a range of wavelengths resulting in a blur of overlapping patterns. This characteristic of laser light makes it ideal for the experimental study of diffraction phenomena.

What is the point of this experiment?

You are going to use diffraction grating to measure the wavelength of laser light, diffraction grating consists of a large number of fine, evenly spaced parallel slits, the condition required for a diffraction grating to produce bright frings is the same as for double-slit setup

$$d \sin\theta = m\,\lambda$$

Where m is the order number, $m = 0, 1, 2, 3 \ldots\ldots$, $\lambda =$ wavelength and $d =$ distance between lines (slit width). As seen in the graph.



What is the experiment about?

You will determine the laser's wavelength by using diffraction grating. Read the description in the manual, also see the book: (Alfezia Altjrebia, "Practical physics" by Mohamed Sallem, (2000) الفيزياء التجريبية لمحمد سالم)

What will I be doing?

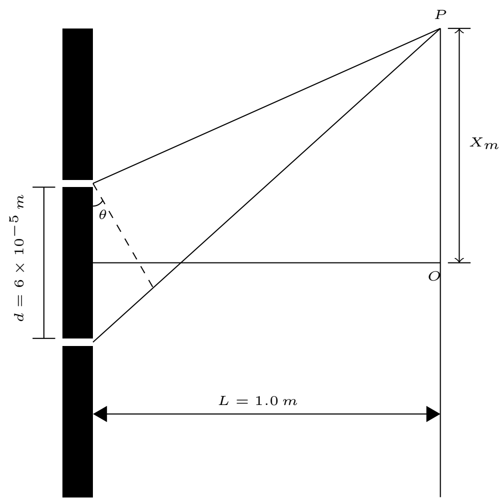
Read the description in the manual, also see the book: (Alfezia Altjrebia, "Practical physics" by Mohamed Sallem, (2000) الفيزياء التجريبية لمحمد سالم) and answer these questions:

1. What are the laser beam properties?
2. Which type of laser do you use?
3. What is the definition of diffraction?

B.3.2 Post-Lab

Answer these questions

1. Is it suitable to use a single slit if we need to separate light of different wavelength with high resolution? Explain your answer.
2. What is the colour of monochromatic light source if the distance to the second order bright fringe is 20 millimetre? and the slit width equal to 6.0 $\times$ $10^{-5}\,m$.



   (a) Blue.
   (b) Green.
   (c) Orange.
3. When 675 nm light passes through diffraction grating, a second-order principle maximum is observed at an angle of 20°. Which mathematical formula should you use to calculate the number of slits per centimetre for this grating?

B.3.3 Data from Questionnaire used after Third Experiment

See D.1 for the original question. Responses for question one, part one:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (a)	*This experiment was easy to do*					
With Pre-lab	45	25	37	0	22	16
Without Pre-lab	50	22	24	0	30	24
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*					
With Pre-lab	45	40	33	7	13	7
Without Pre-lab	50	24	20	2	30	24
Q1 (c)	*Preparation for the lab was not very helpful in following the experimental procedure*					
With Pre-lab	45	7	9	20	35	29
Without Pre-lab	50	24	22	16	14	24
Q1 (d)	*Having done this experiment I now find the topic more interesting*					
With Pre-lab	45	29	38	9	13	11
Without Pre-lab	50	14	20	10	30	26
Q1 (e)	*I found this experiment was difficult*					
With Pre-lab	45	16	22	0	38	24
Without Pre-lab	50	22	32	0	24	22
Q1 (f)	*When I started this experiment, I didn't know what its purpose was*					
With Pre-lab	45	9	13	5	35	38
Without Pre-lab	50	26	28	2	22	22
Q1 (g)	*Apparatus used in this experiment was difficult to handle*					
With Pre-lab	45	13	20	7	22	38
Without Pre-lab	50	24	26	4	26	20
Q1 (h)	*Preparation for this experiment not contributed to my understanding of the course*					
With Pre-lab	45	7	20	11	40	22
Without Pre-lab	50	32	30	10	14	14
Q1 (i)	*I could not do a similar experiment on my own without further instruction*					
With Pre-lab	45	7	13	20	36	24
Without Pre-lab	50	24	12	30	20	14
Q1 (j)	*My preparation for this experiment made me not interested in the subject.*					
With Pre-lab	45	9	15	9	38	29
Without Pre-lab	50	24	30	12	22	12

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question one, part two:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*					
With Pre-lab	45	29	33	9	16	13
Without Pre-lab	50	12	14	16	30	28
Q1 (l)	*It was easy to follow the laboratory manual*					
With Pre-lab	45	31	33	7	22	7
Without Pre-lab	50	20	22	8	28	22
Q1 (m)	*For this experiment it was easy to use the apparatus*					
With Pre-lab	45	40	20	7	22	11
Without Pre-lab	50	20	26	4	24	26
Q1 (n)	*I successfully completed this experiment within the prescribed time*					
With Pre-lab	45	49	29	0	15	7
Without Pre-lab	50	30	26	0	24	20
Q1 (o)	*I need more information on how to prepare for this experiment*					
With Pre-lab	45	13	16	9	35	27
Without Pre-lab	50	28	30	18	12	12
Q1 (p)	*Experimental procedure was more clear due to my preparation*					
With Pre-lab	45	27	37	20	9	7
Without Pre-lab	50	22	16	16	22	24
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*					
With Pre-lab	45	22	38	20	11	9
Without Pre-lab	50	14	20	30	12	24
Q1 (r)	*The experiment helped me to understand some of the course work*					
With Pre-lab	45	22	40	11	20	7
Without Pre-lab	50	14	14	10	32	30
Q1 (s)	*The procedure was not clearly explained in the lab manual*					
With Pre-lab	45	5	24	7	33	31
Without Pre-lab	50	24	26	8	22	20
Q1 (t)	*Not enough time was given to complete the experiment*					
With Pre-lab	45	9	13	0	31	47
Without Pre-lab	50	22	22	0	26	30

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question two:

Group	**N**		%						
With Pre-lab	45	*Useful*	42	23	13	9	7	6	*Not useful*
Without Pre-lab	50		38	18	10	12	8	14	
With Pre-lab	45	*Helpful*	25	40	6	5	11	13	*Not helpful*
Without Pre-lab	50		20	38	6	6	14	16	
With Pre-lab	45	*Meaningful*	16	33	22	11	18	0	*Not meaningful*
Without Pre-lab	50		12	30	20	14	20	4	
With Pre-lab	45	*Understandable*	47	24	11	5	13	0	*Not understandable*
Without Pre-lab	50		40	22	12	8	10	8	
With Pre-lab	45	*Satisfying*	20	38	13	11	9	9	*Not satisfying*
Without Pre-lab	50		16	32	14	12	14	12	
With Pre-lab	45	*Interesting*	15	29	22	18	16	0	*Boring*
Without Pre-lab	50		14	28	18	14	14	12	
With Pre-lab	45	*Well-organised*	9	27	31	22	11	0	*Not well-organised*
Without Pre-lab	50		8	24	30	20	12	6	

B.4 Experiment 4: Rotation of plane of polarisation with sugar solutions

B.4.1 Pre-Lab

You should read the Pre-Lab sheet before you come to the lab. The staff in the lab will check if you did or not.

What should I know before I begin?

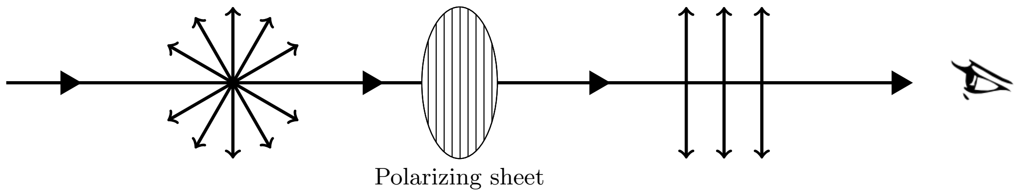
You should know:

- You should be familiar with the phenomena of polarisation.
- What is the optical activity.
- How to use polarimeter.
- What is the angle of rotation.

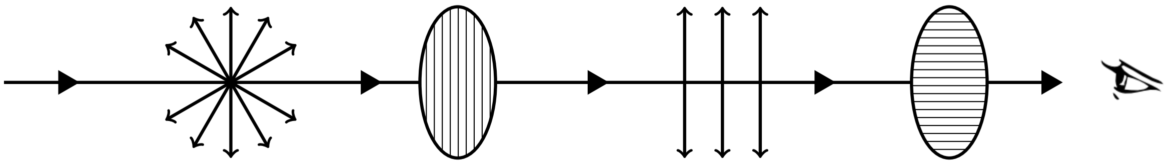
After you know the above please answer this question:

- What are the types of polarisation?

Ideas of Polarisation by figures:



A polarised sheet produces plane-polarised light from unpolarised light, and the parallel lines which are not actually visible on the sheet, suggest the characteristic polarising direction of the sheet.



In the figure above,unpolarised light is not transmitted by crossed polarising sheets.

What does a polarimeter do?

Polarimeter is an instrument for measuring the state of polarisation of a beam of light or other form of electromagnetic radiation. It is designed to detect and measure the rotation of plane-polarised light. The rotation is directly proportional to the number of optically active molecules in the path of the light. If the sample tube is long, there will be many molecules, and the rotation will be large. Similarly, if the concentration of the sample is high, there will also be many molecules, and the rotation will be large.

Mathematically the relationship for optical rotation is $[\alpha] = \dfrac{\theta}{cl}$

Where l is the length of the tube in decimetres (dm) and c is the concentration of the solution in g/ml. θ is the angle of optical rotation, The specific rotation, α is the specific rotation.

What is the experiment about?

This experiment about the phenomena of Optical activity which is a property of several substances by which the plane of polarisation of linearly polarised light is rotated on passing through the substance. This phenomenon occurs, among other things, in some solutions. Here the molecular structure of the dissolved substance leads to right-circularly and left-circularly polarised light propagating at different phase velocities in the solution. Linearly polarised light which enters the solution can be decomposed into a right-circularly and a left-circularly polarised partial wave. The two partial waves propagate at different phase velocities so that a phase difference arises, which is proportional to the distance covered. After the two partial waves have covered this distance, their superposition results in a linearly polarised wave whose direction of polarisation is rotated relative to the original.

What will I measure?

- You will observe the rotation of the plane of polarisation by concentrated sugar solution in an arrangement of two crossed polarisers.
- You will determine the angle of rotation of the plane of polarisation with sugar solution.

for more information about this experiment(see Alfezia Altjrebia, “Practical physics” by Mohamed Sallem,(2000) الفيزياء التجريبية لمحمد سالم

B.4.2 Post-Lab

Answer these questions

1. What does it meant by polarisation of waves? .
2. What does polarisation of light tell about the nature of light?
3. Give examples of the applications of polarization in our life?
4. What are the factors which act on the angle of rotation?
5. Which wave phenomenon can be used to distinguish between transverse waves and longitudinal waves?
6. Explain in your own words the meaning of the term 'optical activity'.

B.4.3 Data from Questionnaire used after Fourth Experiment

See D.1 for the original question. Responses for question one, part one:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (a)	*This experiment was easy to do*					
With Pre-lab	50	32	34	0	28	6
Without Pre-lab	45	29	22	0	27	22
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*					
With Pre-lab	50	28	42	8	20	2
Without Pre-lab	45	20	26	7	25	22
Q1 (c)	*Preparation for the lab was not very helpful in following the experimental procedure*					
With Pre-lab	50	4	12	14	20	50
Without Pre-lab	45	29	18	16	20	17
Q1 (d)	*Having done this experiment I now find the topic more interesting*					
With Pre-lab	50	28	34	8	22	8
Without Pre-lab	45	22	20	5	24	29
Q1 (e)	*I found this experiment was difficult*					
With Pre-lab	50	4	30	0	34	32
Without Pre-lab	45	20	29	0	22	29
Q1 (f)	*When I started this experiment, I didn't know what its purpose was*					
With Pre-lab	50	4	18	8	40	30
Without Pre-lab	45	22	25	7	24	22
Q1 (g)	*Apparatus used in this experiment was difficult to handle*					
With Pre-lab	50	4	26	2	30	38
Without Pre-lab	45	33	25	2	20	20
Q1 (h)	*Preparation for this experiment not contributed to my understanding of the course*					
With Pre-lab	50	4	12	24	44	16
Without Pre-lab	45	33	14	15	20	18
Q1 (i)	*I could not do a similar experiment on my own without further instruction*					
With Pre-lab	50	26	30	28	8	8
Without Pre-lab	45	29	29	20	15	7
Q1 (j)	*My preparation for this experiment made me not interested in the subject.*					
With Pre-lab	50	8	22	8	36	26
Without Pre-lab	45	27	22	2	29	20

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question one, part two:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*					
With Pre-lab	50	30	36	12	20	2
Without Pre-lab	45	16	26	11	22	25
Q1 (l)	*It was easy to follow the laboratory manual*					
With Pre-lab	50	28	36	4	30	2
Without Pre-lab	45	16	29	2	29	24
Q1 (m)	*For this experiment it was easy to use the apparatus*					
With Pre-lab	50	36	32	2	26	4
Without Pre-lab	45	20	20	2	33	25
Q1 (n)	*I successfully completed this experiment within the prescribed time*					
With Pre-lab	50	52	18	0	24	6
Without Pre-lab	45	18	26	0	34	22
Q1 (o)	*I need more information on how to prepare for this experiment*					
With Pre-lab	50	4	18	12	38	28
Without Pre-lab	45	25	22	11	26	16
Q1 (p)	*Experimental procedure was more clear due to my preparation*					
With Pre-lab	50	20	50	14	10	6
Without Pre-lab	45	17	20	16	20	27
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*					
With Pre-lab	50	6	10	28	30	26
Without Pre-lab	45	7	15	20	27	31
Q1 (r)	*The experiment helped me to understand some of the course work*					
With Pre-lab	50	14	46	24	12	4
Without Pre-lab	45	18	20	15	16	31
Q1 (s)	*The procedure was not clearly explained in the lab manual*					
With Pre-lab	50	4	28	4	36	28
Without Pre-lab	45	24	29	2	27	18
Q1 (t)	*Not enough time was given to complete the experiment*					
With Pre-lab	50	6	24	0	20	20
Without Pre-lab	45	22	34	0	26	18

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question two:

Group	**N**		%						
With Pre-lab	50	*Useful*	46	28	6	12	2	6	*Not useful*
Without Pre-lab	45		31	18	13	11	13	14	
With Pre-lab	50	*Helpful*	26	46	6	10	8	4	*Not helpful*
Without Pre-lab	45		27	26	7	15	14	11	
With Pre-lab	50	*Meaningful*	12	38	24	4	20	2	*Not meaningful*
Without Pre-lab	45		16	22	18	9	22	13	
With Pre-lab	50	*Understandable*	48	28	2	4	14	4	*Not understandable*
Without Pre-lab	45		29	22	13	12	13	11	
With Pre-lab	50	*Satisfying*	6	32	34	14	12	2	*Not satisfying*
Without Pre-lab	45		13	25	11	15	14	22	
With Pre-lab	50	*Interesting*	8	32	30	22	6	2	*Boring*
Without Pre-lab	45		20	24	18	13	9	16	
With Pre-lab	50	*Well-organised*	2	32	32	20	12	2	*Not well-organised*
Without Pre-lab	45		15	27	18	18	13	9	

B.5 Experiment 5: Determination of the distance between planes of ions in crystals using X-rays

B.5.1 Pre-Lab

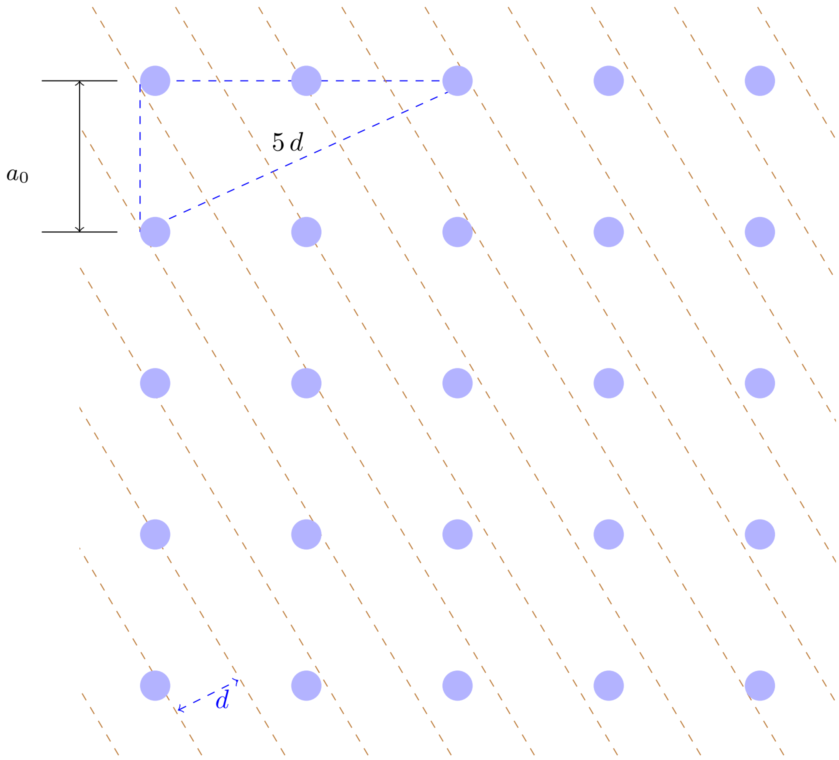
You should read the Pre-Lab sheet before you come to the lab. The staff in the lab will check if you did or not.

What should I know before I begin?

Should know:

- You should be familiar with some ideas about crystals, and what the inter-atomic distance means.
- You should be familiar with how X-rays Crystal Spectrometer is working by reading the description in the manual, (and for more information see: Optics by Dakheel, A. 1988).
- You should be familiar with The Bragg conditions. (See optics by Dakheel, A. 1988).
- What is the meaning of the term angle of incidence in X-rays diffraction.

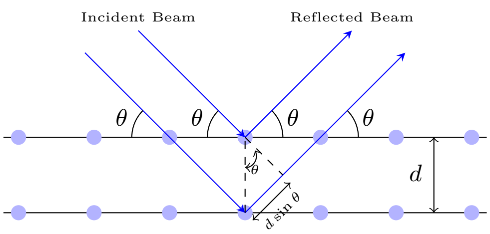
Ideas about the structure of crystals are shown in the below figure.



What can I do with the use of X-rays?

- In this experiment X-Rays are used to determine the structure of crystals and molecules.
- X-rays diffraction is used to determine crystal structures by interpreting the diffraction patterns formed when X-rays are scattered by the electrons of atoms in crystalline solids. X-rays are sent through a crystal to reveal the pattern in which the molecules arranged.
- The spectrum of X-rays emitted by an atom gives information about the structure of that atom which is absolutely necessary for a deeper understanding of its physical properties.

Scattering of X-rays from crystal is shown in the below figure.



Why use X-rays in this practical?

- You are going to measure the inter-atomic (or ionic) distances in a solid, to do this you have to use radiation, and the wavelength of X-rays is similar in size to the distances being measured.

What will I measure in this experiment?

- You will measure inter-atomic distances in crystals of LiF, KCl and NaCl.

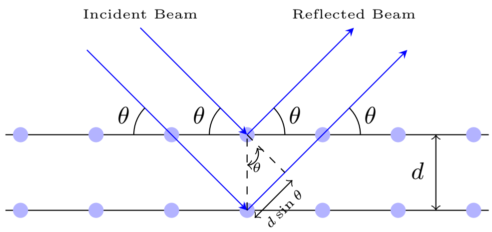
What will I be doing?

- The first part of this experiment is to measure X-rays spectrum and d for LiF, KCl and NaCl, (read the description in the manual and follow it)
  - First: X-rays spectrum and d for LiF crystal.
  - Second X-rays spectrum and d for KCL crystal.
  - Third: X-rays spectrum and d for NaL crystal.
- The second part of this experiment is X-rays absorption:
  - First: Measure the scattered X-rays spectrum from the LiF crystal with nickel foil.
  - Second: Repeat above step for copper and cobalt foils.
  - Third: Plat the spectra for the three different foils on the same graph and compare them.
  - Fourth: Repeat the second part by using the other two crystals (KCL, and NaL).

B.5.2 Post-Lab

Answer this questions.

1. Why we use X-rays not visible rays in the study of the structure of solids?
2. Do you know other application for X-rays?
3. At what angles must an X-rays beam with $\lambda = 0.110\,nm$ fall on the family of planes represented in the figure below if the diffracted beam is to exist? Assume the material to be sodium chloride where $a = 0.563\,nm$. Explain your answer.



B.5.3 Data from Questionnaire used after Fifth Experiment

See D.1 for the original question. Responses for question one, part one:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (a)	*This experiment was easy to do*					
With Pre-lab	50	28	48	0	10	14
Without Pre-lab	45	22	22	0	29	27
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*					
With Pre-lab	50	46	30	0	16	8
Without Pre-lab	45	22	18	7	24	29
Q1 (c)	*Preparation for the lab was not very helpful in following the experimental procedure*					
With Pre-lab	50	6	12	10	46	26
Without Pre-lab	45	33	29	11	13	14
Q1 (d)	*Having done this experiment I now find the topic more interesting*					
With Pre-lab	50	40	38	6	12	4
Without Pre-lab	45	9	24	11	40	16
Q1 (e)	*I found this experiment was difficult*					
With Pre-lab	50	14	10	0	46	30
Without Pre-lab	45	29	27	0	22	22
Q1 (f)	*When I started this experiment, I didn't know what its purpose was*					
With Pre-lab	50	8	16	0	32	44
Without Pre-lab	45	24	29	7	20	20
Q1 (g)	*Apparatus used in this experiment was difficult to handle*					
With Pre-lab	50	18	8	0	26	48
Without Pre-lab	45	28	27	9	18	18
Q1 (h)	*Preparation for this experiment not contributed to my understanding of the course*					
With Pre-lab	50	6	20	16	36	22
Without Pre-lab	45	30	27	16	22	5
Q1 (i)	*I could not do a similar experiment on my own without further instruction*					
With Pre-lab	50	10	12	22	40	16
Without Pre-lab	45	24	18	29	16	13
Q1 (j)	*My preparation for this experiment made me not interested in the subject.*					
With Pre-lab	50	4	12	6	36	42
Without Pre-lab	45	18	38	11	9	24

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question one, part two:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*					
With Pre-lab	50	34	42	2	8	14
Without Pre-lab	45	13	16	9	31	31
Q1 (l)	*It was easy to follow the laboratory manual*					
With Pre-lab	50	34	42	2	16	6
Without Pre-lab	45	11	18	7	27	37
Q1 (m)	*For this experiment it was easy to use the apparatus*					
With Pre-lab	50	48	26	0	10	16
Without Pre-lab	45	20	16	9	29	26
Q1 (n)	*I successfully completed this experiment within the prescribed time*					
With Pre-lab	50	58	18	0	18	6
Without Pre-lab	45	27	13	0	31	29
Q1 (o)	*I need more information on how to prepare for this experiment*					
With Pre-lab	50	12	10	2	42	34
Without Pre-lab	45	31	31	11	14	13
Q1 (p)	*Experimental procedure was more clear due to my preparation*					
With Pre-lab	50	24	48	10	12	6
Without Pre-lab	45	14	13	11	31	31
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*					
With Pre-lab	50	16	40	22	10	12
Without Pre-lab	45	13	16	29	18	24
Q1 (r)	*The experiment helped me to understand some of the course work*					
With Pre-lab	50	20	38	16	20	6
Without Pre-lab	45	7	20	16	29	28
Q1 (s)	*The procedure was not clearly explained in the lab manual*					
With Pre-lab	50	6	16	2	40	36
Without Pre-lab	45	35	29	9	16	11
Q1 (t)	*Not enough time was given to complete the experiment*					
With Pre-lab	50	4	20	0	18	58
Without Pre-lab	45	29	31	0	13	27

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question two:

Group	**N**		%						
With Pre-lab	50	*Useful*	44	26	16	2	8	4	*Not useful*
Without Pre-lab	45		18	17	16	9	20	20	
With Pre-lab	50	*Helpful*	26	42	12	10	8	2	*Not helpful*
Without Pre-lab	45		7	26	9	20	18	20	
With Pre-lab	50	*Meaningful*	22	36	20	16	6	0	*Not meaningful*
Without Pre-lab	45		9	20	16	26	18	11	
With Pre-lab	50	*Understandable*	44	24	12	4	16	0	*Not understandable*
Without Pre-lab	45		18	15	13	7	14	33	
With Pre-lab	50	*Satisfying*	4	34	38	12	8	4	*Not satisfying*
Without Pre-lab	45		13	20	12	13	20	22	
With Pre-lab	50	*Interesting*	8	44	24	8	16	0	*Boring*
Without Pre-lab	45		16	22	16	17	20	9	
With Pre-lab	50	*Well-organised*	2	28	40	22	8	0	*Not well-organised*
Without Pre-lab	45		16	11	27	15	15	16	

Appendix C

Third Stage Appendix

C.1 Experiment 1: Determination of the refractive index of a glass prism using a spectrometer

C.1.1 Pre-Lab

You should read the Pre-Lab sheet before you come to the lab. The staff in the lab will check if you did or not.

What should I know before I begin?

You should know:

- You should be familiar with the phenomena of refraction.
- You should be familiar with how to set up and adjust the spectrometer.
- You should be sufficiently familiar with how to use spectrometer.
- You should know what the angle of deviation means and it's relation with the angle of incident.

What does a spectrometer do?

You will use a spectrometer as an instrument for determining the refractive index of a glass prism. The simple spectrometer consists of three parts:

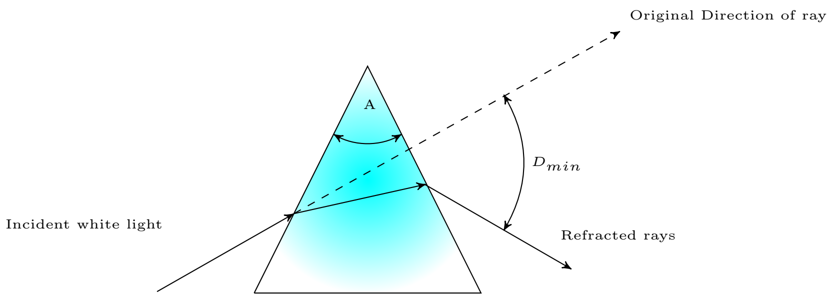
- The collimator which provides a parallel beam of light from the source. It consists of a tube with an achromatic lens at one end and an adjustable slit at the other.
- The prism which disperses the light received from the collimator.
- The telescope which receives the dispersed light from the prism. It is provided with an eyepiece fitted with cross-hairs.

Why use it in this practical?

A spectrometer is ideal for the objective of this experiment.

What is the experiment about?

- You will determine the refractive index of a glass prism a using spectrometer.



What will I be doing?

Read the description in the manual; also see the book (Alfezia Altjrebia, "Practical physics" by Mohamed Salem(2000) الفيزياء التجريبية لمحمد سالم) After you do the above please answer these questions:

1. Why does the phenomena of refraction occur?
2. Define the term refractive index.
3. Define the angle of deviation.

C.1.2 Instruction Sheet

Objective:

Determination of the refractive index of glass prism using a spectrometer.

Apparatus:

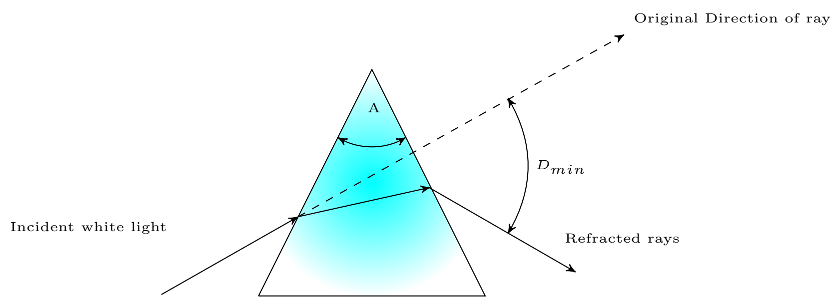
Spectrometer, prism, sodium light, power supply, and magnifying glass.

Theory:

When the sodium light passes through a prism it is refracted two times, first one at the entrance of the prism and second as it leaves the prism as shown in the figure below. Angle (A) is called the prism angle, the head of the prism where the planes of refraction intersect is called the refractive edge of the prism and the angle between incident ray and emergent ray is called the angle of deviation D_{min}. The minimum value of this angle is when the angle of emergent is equal to the angle of incident and this is the property of the prism. The refractive index can be calculated by equation:

$$n = \frac{\sin(\frac{A+D_{min}}{2})}{\sin(\frac{A}{2})}$$

Where A is the prism angle, D_{min} is the measured angle of minimum deviation.



Procedures:

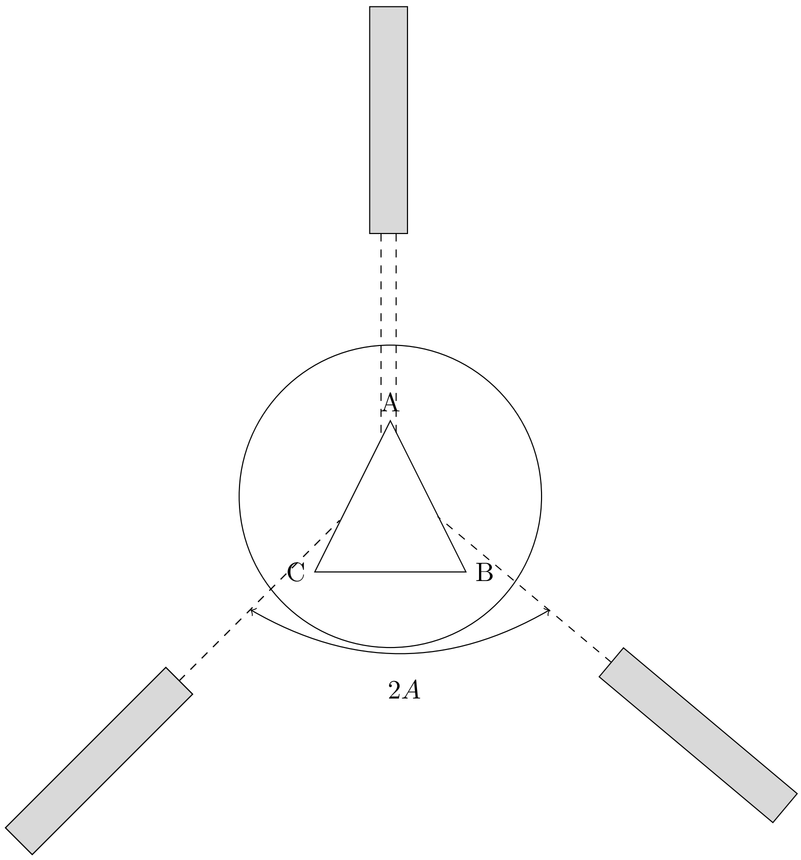
First part: adjustment of spectrometer

1. The prism should not on the turntable, and both spectrometer and prism table should be in a horizontal position.
2. Adjust the spectrometer by moving the instrument until you can point the telescope at a distance object to receive a clear and sharp image.
3. The slit is illuminated by sodium light lamb and the slit and collimator are suitably adjusted to receive a narrow vertical image of the slit.
4. Now the telescope is turned to receive the direct ray, so the vertical slit coincides with the vertical cross wire.

Second part: measuring the angle of the prism and deviation angle:

1. Put the prism on the turntable, and rotate the turntable until the refracting edge of the prism is approximately pointing toward the collimator.
2. Rotate the telescope until the first reflected slit image is centred on the cross wires then record the reading of the two verniers.
3. Again and without moving the prism swing the telescope until the other reflected image of the slit is centred on the cross wires then record the angle of telescope from other side. The angle between the two telescope positions is twice the angle of the prism (A).
4. Repeat the above two or three times, moving the position of the prism slightly between each set of reading, then calculate the mean for the angle of prism.
5. To measure the minimum angle of deviation, you have to rotate both turntable and telescope until light will pass approximately symmetrically through the prism.

6. Rotate the telescope until the succession of views, note the reading of two verniers.
7. Turn the prism table and bring the telescope in the line of the collimator, see the slit directly through telescope and coincide the image of slit with vertical cross wire, and record the reading of two verniers.
8. The angle between the two telescope positions from step (6) and (7) is the minimum deviation angle D_{min}.



Precautions:

1. It must be ensured that the light rays coming out of the collimator are parallel, for that, the collimator must be focused properly before the experiment.
2. The plane on which the prism rests must be horizontal.
3. The slit must be as thin as possible in order to avoid diffraction.
4. The prism should be properly placed on the prism table.

Observations:

- Value of the division of the main scale = ………degrees.
- Total number of vernier division = ………
- Least count of the vernier = ………degrees ………second.

First part angle of the prism:

No.	Telescope 1^{st} position	Telescope 2^{nd} position	Difference $2A°$	Mean $2A°$
1-				
2-				
3-				

Second part the angle of minimum deviation:

No.	Telescope reading for minimum deviation (a)	Telescope reading for direct image (b)	Difference $D_{min} = a - b$	Mean D_{min}
1-				
2-				
3-				

Calculation:

- Angle of prism = ………
- Angle of minimum deviation = ………
- Refractive index (n) = ………
- Estimated error is………

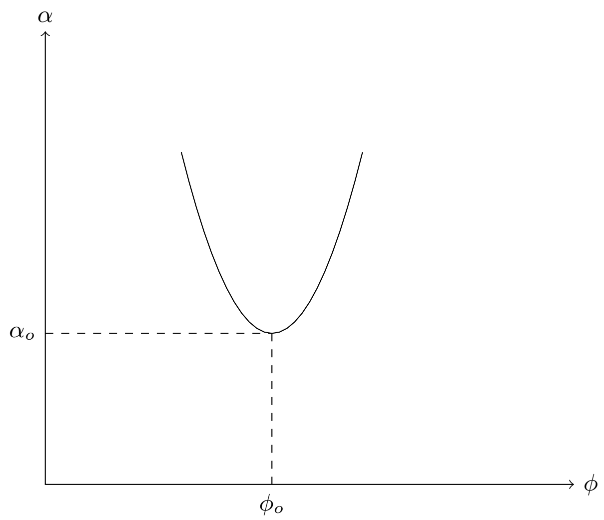
for more information about this experiment(see Alfezia Altjrebia, "Practical physics" by Mohamed Salem(2000) الفيزياء التجريبية لمحمد سالم

C.1.3 Post-lab

This test seeks to test your ability to understand some ideas in optics. The marks from this test will not affect your university grades in any way. Most of the answers can be shown by writing a number or ticking a box.

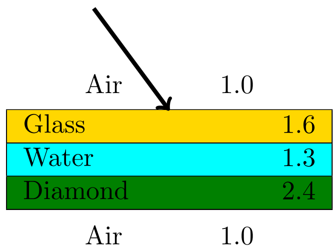
Answer all questions:

1. In the diagram below: the y-axis represents the angle of deviation (α) in the triangular prism, the x-axis represents the angle of incident (ϕ). Explain this diagram and what does (α_o) mean?



2. Dispersion occurs when:
   (a) Some materials bend light more than other materials.
   (b) A material slows down some colours more than others.
   (c) A material changes some colours more than others.
   (d) Light has different speeds in different materials.
3. A light ray in air enters and passes through a block of glass. What can be said about its speed after it emerges from the block?
   (a) Speed is less than when in glass
   (b) Speed is less than before it entered glass
   (c) Speed is the same as that in glass
   (d) Speed is the same as that before it entered glass

4. When white light is dispersed using a prism, the violet colour has greatest deviation, because its speed through the prism is: (Tick all that are true)
   (a) Small and refractive index is small.
   (b) Big and refractive index is big
   (c) Small and refractive index is big.
   (d) Big and refractive index is small.
5. Perform the necessary calculations at each boundary in order to trace the path of the light ray through the following series of layers. Use a protractor and a ruler and show all your work.



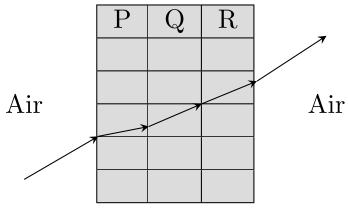
6. Liquid and solid have the same refractive index. What happen to the speed and the wave length of light passing from the liquid into the solid?

		Speed	Wave length
	A	Stay the same	Stay the same
	B	Decrease	Decrease
	C	Decrease	Increase
	D	Increase	Increase
	E	Increase	Decrease

7. If there is a decorative lamp in your bedroom with a transparent liquid in the space above a light bulb. The light from the bulb passes through rotating coloured filters giving red or blue light in the liquid. A ray of red light is incident on the liquid surface with incident angle equal to 45° and refractive angle equal to 82°. A ray of blue light is incident on the liquid surface at the same angle as the ray of red light.
   (a) Is the refractive index of liquid for blue light is greater than for red light?………
   (b) Is the angle of refraction greater than, equal to, or less than 82° for the blue light?………
8. Light travels from air to glass.Which row in the table describes what happen to the speed, frequency, and wavelength of the light?

		Speed	Frequency	Wave length
	A	Increases	Stays constant	Increases
	B	Increases	Decreases	Stays constant
	C	Stays constant	Decreases	Decreases
	D	Decreases	Decreases	Stays constant
	E	Decreases	Stays constant	Decreases

9. A university student creates an experimental window using sheets of transparent plastic P, Q, R. A ray of light directed at the window follows the path shown:



Which row in the table gives possible values for the refractive indices of the three plastics?

		P	Q	R
	A	1.5	1.9	2.3
	B	1.5	1.5	2.3
	C	2.3	2.3	1.5
	D	2.3	1.9	1.5
	E	1.5	1.5	1.2

10. Explain how mirage could occur? two to three lines only.

. . . .

. . . .

C.1.4 Data from Questionnaire used after First Experiment

See D.2 for the original question. Responses for question one, part one:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (a)	*This experiment was easy to do*					
With Pre-lab	56	27	43	7	14	9
Without Pre-lab	50	20	22	12	24	22
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*					
With Pre-lab	56	36	33	11	15	5
Without Pre-lab	50	18	18	8	30	26
Q1 (c)	*Preparation for the lab was not very helpful in following the experimental procedure*					
With Pre-lab	56	11	11	11	52	15
Without Pre-lab	50	32	32	12	12	12
Q1 (d)	*Having done this experiment I now find the topic more interesting*					
With Pre-lab	56	39	29	9	14	9
Without Pre-lab	50	12	12	10	36	30
Q1 (e)	*I found this experiment was difficult*					
With Pre-lab	56	11	12	7	43	27
Without Pre-lab	50	22	24	12	22	20
Q1 (f)	*When I started this experiment, I didn't know what its purpose was*					
With Pre-lab	56	7	13	11	33	36
Without Pre-lab	50	28	28	8	18	18
Q1 (g)	*Apparatus used in this experiment was difficult to handle*					
With Pre-lab	56	9	13	7	39	32
Without Pre-lab	50	32	32	12	12	12
Q1 (h)	*Preparation for this experiment not contributed to my understanding of the course*					
With Pre-lab	56	9	9	9	46	27
Without Pre-lab	50	32	28	10	16	14
Q1 (i)	*I could not do a similar experiment on my own without further instruction*					
With Pre-lab	56	11	16	11	34	28
Without Pre-lab	50	30	30	18	8	14
Q1 (j)	*My preparation for this experiment made me not interested in the subject.*					
With Pre-lab	56	9	14	9	31	37
Without Pre-lab	50	30	36	10	12	12

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question one, part two:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*					
With Pre-lab	56	29	39	9	12	11
Without Pre-lab	50	10	10	10	30	40
Q1 (l)	*It was easy to follow the laboratory manual*					
With Pre-lab	56	45	25	5	13	12
Without Pre-lab	50	22	28	12	20	18
Q1 (m)	*For this experiment it was easy to use the apparatus*					
With Pre-lab	56	32	39	9	11	9
Without Pre-lab	50	12	12	12	30	34
Q1 (n)	*I successfully completed this experiment within the prescribed time*					
With Pre-lab	56	41	34	11	14	0
Without Pre-lab	50	24	32	10	18	16
Q1 (o)	*I need more information on how to prepare for this experiment*					
With Pre-lab	56	11	12	11	39	27
Without Pre-lab	50	40	30	10	10	10
Q1 (p)	*Experimental procedure was more clear due to my preparation*					
With Pre-lab	56	14	52	11	12	11
Without Pre-lab	50	12	12	10	32	34
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*					
With Pre-lab	56	26	36	11	13	14
Without Pre-lab	50	12	10	18	30	30
Q1 (r)	*The experiment helped me to understand some of the course work*					
With Pre-lab	56	25	48	9	9	9
Without Pre-lab	50	14	16	10	28	32
Q1 (s)	*The procedure was not clearly explained in the lab manual*					
With Pre-lab	56	12	13	7	25	43
Without Pre-lab	50	18	20	12	26	24
Q1 (t)	*Not enough time was given to complete the experiment*					
With Pre-lab	56	0	14	11	34	41
Without Pre-lab	50	14	20	10	32	24

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question two:

Group	**N**		%						
With Pre-lab	56	*Useful*	34	27	11	7	11	10	*Not useful*
Without Pre-lab	50		22	16	12	12	20	18	
With Pre-lab	56	*Helpful*	29	34	7	9	11	10	*Not helpful*
Without Pre-lab	50		20	18	12	16	18	16	
With Pre-lab	56	*Meaningful*	30	32	11	9	9	9	*Not meaningful*
Without Pre-lab	50		16	22	18	16	14	14	
With Pre-lab	56	*Understandable*	34	32	5	11	11	7	*Not understandable*
Without Pre-lab	50		18	18	12	20	16	16	
With Pre-lab	56	*Satisfying*	29	32	11	10	9	9	*Not satisfying*
Without Pre-lab	50		14	16	16	18	16	20	
With Pre-lab	56	*Interesting*	29	32	9	11	9	10	*Boring*
Without Pre-lab	50		20	16	26	14	12	12	
With Pre-lab	56	*Well-organised*	14	45	9	9	11	12	*Not well-organised*
Without Pre-lab	50		14	14	12	16	20	24	

Responses for question three:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q3 (a)	*I found discussions boring.*					
With Pre-lab	56	16	13	12	28	30
Without Pre-lab	50	20	18	0	28	34
Q3 (b)	*I enjoyed working with members of my group.*					
With Pre-lab	56	34	25	12	14	15
Without Pre-lab	50	30	34	10	12	14
Q3 (c)	*Most of the ideas were not helpful.*					
With Pre-lab	56	11	12	20	25	32
Without Pre-lab	50	22	20	10	22	26
Q3 (d)	*Most of the ideas came from one person.*					
With Pre-lab	56	11	12	20	25	32
Without Pre-lab	50	16	14	12	28	30
Q3 (e)	*Working as a group made it easier for us to get answers.*					
With Pre-lab	56	37	30	9	12	11
Without Pre-lab	50	30	30	14	12	14
Q3 (f)	*I did not respect ideas from others since they are always wrong.*					
With Pre-lab	56	12	11	11	29	37
Without Pre-lab	50	14	12	12	32	30

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

C.2 Experiment 2: Determination of the wavelength of sodium light using Newton's Rings

C.2.1 Pre-Lab

You should read the Pre-Lab sheet before you come to the lab. The staff in the lab will check if you did or not.

What should I know before I begin?

- You should have knowledge about interference.
- You should know how the travelling microscope works, (see Alfezia Altjrebia, "Practical physics" by Mohamed Salem (2000)الفيزياء التجريبية لمحمدسالم, page 315).
- You should know the accepted value of the wave length of sodium light
- You should know information about the nature of sodium light.
- You should know about the plane convex lens.

After you know the above please ask yourself these questions:

- What is the definition of interference?
- What are the types of interference, and what are the conditions for the interference phenomena to occur?
- What does wavelength mean?

What apparatuses should I use?

You are going to use these apparatuses: Travelling microscope, convex lens, plane convex lens, plane glass plate (optically flat), sodium light source and magnifying torch.

What will I measure and how?

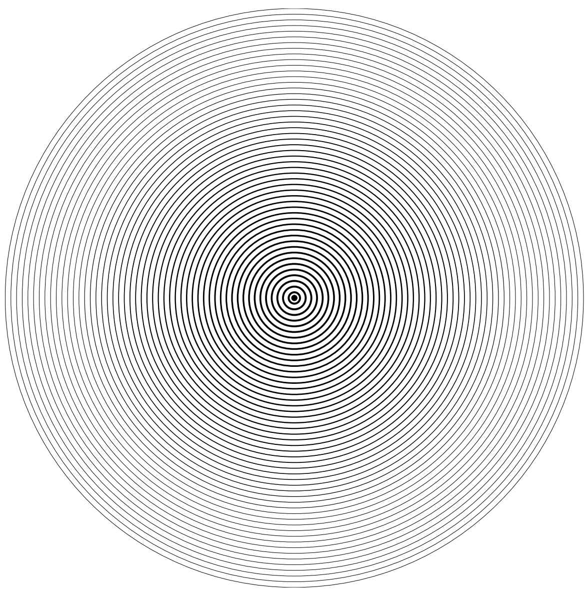
- You will measure the wave length of sodium light.
- Read the instruction sheet, see also the book (Alfezia Altjrebia, "Practical physics" by Mohamed Salem(2000) الفيزياء التجريبية لمحمد سالم)

Why are Newton rings formed?

Newton's rings are formed due to interference between the light waves reflected from the top and bottom surfaces of the air film formed between the lens and glass sheet. The phenomenon of the formation of Newton's Rings can be explained on the basis of wave theory of light:

- An air film of varying thickness is formed between the lens and the glass sheet.
- When a light ray is incident on the upper surface of the lens, it is reflected as well as refracted.
- When the refracted ray strikes the glass sheet, it undergoes a phase change of 180° on reflection.
- Interference occurs between the waves which interfere constructively if path difference between them is $(m + 1/2)\,\lambda$ and destructively if path difference between them is $m\,\lambda$ producing alternate bright and dark rings (Halliday & Resnick, 1988)

The shape of Newton rings are illustrated in the figure below:



C.2.2 Instruction Sheet

Objective:

To measure the wavelength of sodium light using the method of Newton's rings.

Apparatus:

Travelling microscope, convex lens, plane convex lens, plane glass plate (optically flat), sodium light source and Magnifying torch.

Theory:

After the parallel beam from the sodium light source is incident on a plane- convex lens A and glass plate B, reflection and refraction it will occur, some of incident ray will reflect from the lower surface of the lens, and some will refract through the air film between the lens and the plate then it will reflect back from the plate surface. These two reflected rays will interfere and produce a system of alternate dark and bright rings with the point of contact between the lens and the plate as the centre. Which are known as Newton's rings. The path difference between the reflected rays for normal incident is nearly equal to $2dn$, where d is the thickness of the air-film which is equal to 1, and n is the refractive index of the air film.

Therefore, for bright rings:

$$2\,dn = (m + \frac{1}{2})\,\lambda \tag{C.1}$$

Where $m = 0, 1, 2, 3 \ldots\ldots$

For dark rings:

$$m\lambda = 2dn \tag{C.2}$$

Where $m = 0, 1, 2, 3 \ldots\ldots$

The thickness of the air–film is given by this relation:

$$d = R - \sqrt{R^2 - r^2} = R - R\left[1 - \left(\frac{r}{R}\right)^2\right]^{1/2} \tag{C.3}$$

Where (r) is the radius of the bright or dark ring, R is the radius of curvature of the lower surface of the plane-convex lens, but (R>>r) then $1 \;>>\; \left(\frac{r}{R}\right)$, hence $\left(\frac{r}{R}\right)^4$ can be neglected and the equation becomes:

$$d = \frac{r^2}{2R} \tag{C.4}$$

Substitute this in equation C.1 and C.2, you will get:

For the bright ring:

$$r_n^2 = (M + \frac{1}{2})\frac{\lambda\, R}{n} \tag{C.5}$$

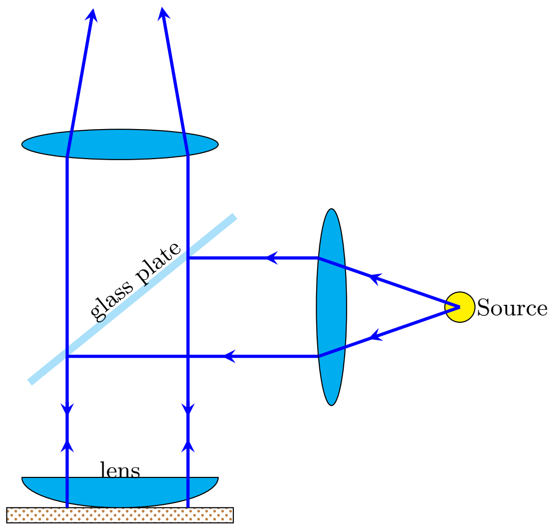
For the dark ring:

$$r_n^2 = \frac{m\,\lambda\, R}{n} \tag{C.6}$$

Procedure:

1. Clean the lens and the glass slides with lens tissue, and place it on the plane glass plate with curved surface in contact with the glass plate and setup the apparatus as shown in figure below
2. Turn on the sodium lamp.

3. Move the telescope of the travelling microscope in the horizontal direction by keeping the microscope itself in stable position until you can clearly view the rings.
4. Adjust the crosswise of the telescope on the centre of sixth bright ring and record the position of vernier and the order number (M).
5. Move the vernier to the right direction and adjust the crosswise of the telescope on the centre of the fifth ring, record the position of vernier and it's order number (M).
6. Repeat step 5 for fourth, third, second, and first ring, and note all the reading which corresponding to each one.
7. Keep moving the vernier to the right direction up to the centre of the first ring in the other side; note the reading for the first ring.
8. Repeat step 7 for the second, third, fourth, fifth and sixth ring, and note all readings corresponding to each one.
9. Calculate the diameter of each ring by subtracting the left side reading from the right side reading for each ring, then calculate the radius (r_m).
10. Draw the graph between r_m^2 and m, you will find a straight line. From the slope of this line and the value of R you can calculate the wavelength of sodium light from the equation: $\lambda = (r_m^2/m)/R$ where (r_m^2/m) is the slope of the graph and R is the radius of curvature of lower surface of the plane-convex lens.



Observations:

Ring no.	Left hand reading (mm)	Right hand reading (mm)	Ring Diameter (mm)	Ring radius r (mm)	r^2 (mm)
1					
2					
3					
4					
5					
6					
7					
8					
9					

Result:

The wavelength of sodium light is………

Estimated error is………

Precaution:

You should not disturb the lens and glass plate combination in any way during the experiment.

for more information about this experiment(see Alfezia Altjrebia, "Practical physics" by Mohamed Salem, (2000) الفيزياء التجريبية لمحمد سالم

C.2.3 Post-lab

This test seeks to test your ability to understand some ideas in optics. The marks from this test will not affect your university grades in any way. Most of the answers can be shown by writing a number or ticking a box.

1. When does the greatest amount of destructive interference occur?
   (a) When they are 1/4 wavelength out phase.
   (b) When they are 1/2 wavelength out phase.
   (c) When they are 3/4 wavelength out phase.
2. If you replace white light source instead of sodium source, you will get:
   (a) The same number of fringes.
   (b) More number of fringes.
   (c) Few numbers of fringes.
3. Think of the Newton rings experiment.Suppose you do not see the black spots in the centre of microscope. Explain why this might happen:

   ....

   ....
4. Explain, why the fringes are circular?

   ....

   ....
5. For what condition does a dark fringe representing destructive interference appear on the screen?
   (a) The path difference is an odd number of wavelengths.
   (b) The path difference is an integral number of half wavelengths.
   (c) The path difference is an odd number of half wavelengths.
6. Look at the table below:

A- Dark and bright lines	B- Intensity of the source
C- Dark and bright spots	D- Frequency of the source
E- Wave length of the source	F- Dark and bright arc
G- Dark and bright rings	H- Energy

   (a) Select the box or boxes which describe the appearance of interference.........
   (b) Select the box or boxes which show factors which affect the clarity of interference.........

7. Can you use point source instead of extended source in the experiment of Newton's ring? And why?

   ....

   ....

8. Let's say you create a Newton's rings pattern with red light, when you switch to green light will the rings in the pattern be larger, smaller, or remain the same size? (select one answer)
   (a) Larger
   (b) Smaller
   (c) The same size
9. Which of the following statements are true statements about interference? Tick all the true statements.
   (a) Interference can be constructive or destructive.
   (b) Interference occurs when two (or more) waves meet while travelling along the same medium.
   (c) Interference of two waves at a given location results in the formation of a new wave pattern which has greater amplitude than either of the two interfering waves.
   (d) The meeting of a trough of one wave with a trough of another wave results in destructive interference.
   (e) The only way for two waves to interfere constructively is for a crest to meet a crest or a trough to meet a trough.
   (f) It is only a theory that light can interfere destructively; the theory is based on the assumption that light is a wave and most waves exhibit this behaviour. Experimental evidence supporting the theory has not yet been observed.
10. If you replace white light source instead of sodium source, you will get:
   (a) The same number of fringes.
   (b) More number of fringes.
   (c) Few numbers of fringes.

C.2.4 Data from Questionnaire used after Second Experiment

See D.2 for the original question. Responses for question one, part one:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (a)	*This experiment was easy to do*					
With Pre-lab	56	36	32	9	12	11
Without Pre-lab	50	20	14	10	26	30
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*					
With Pre-lab	56	37	30	7	13	12
Without Pre-lab	50	18	14	12	32	24
Q1 (c)	*Preparation for the lab was not very helpful in following the experimental procedure*					
With Pre-lab	56	11	12	11	34	32
Without Pre-lab	50	32	32	12	12	12
Q1 (d)	*Having done this experiment I now find the topic more interesting*					
With Pre-lab	56	32	30	13	14	11
Without Pre-lab	50	12	14	10	32	32
Q1 (e)	*I found this experiment was difficult*					
With Pre-lab	56	12	11	9	34	34
Without Pre-lab	50	30	26	12	12	20
Q1 (f)	*When I started this experiment, I didn't know what its purpose was*					
With Pre-lab	56	11	12	11	32	34
Without Pre-lab	50	24	32	12	12	20
Q1 (g)	*Apparatus used in this experiment was difficult to handle*					
With Pre-lab	56	12	15	11	28	34
Without Pre-lab	50	28	30	12	18	12
Q1 (h)	*Preparation for this experiment not contributed to my understanding of the course*					
With Pre-lab	56	7	12	11	21	49
Without Pre-lab	50	34	32	14	10	10
Q1 (i)	*I could not do a similar experiment on my own without further instruction*					
With Pre-lab	56	13	16	9	30	32
Without Pre-lab	50	36	30	10	14	10
Q1 (j)	*My preparation for this experiment made me not interested in the subject.*					
With Pre-lab	56	11	14	11	32	32
Without Pre-lab	50	32	30	12	14	12

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question one, part two:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*					
With Pre-lab	56	37	34	11	11	7
Without Pre-lab	50	12	14	12	32	30
Q1 (l)	*It was easy to follow the laboratory manual*					
With Pre-lab	56	37	34	11	7	11
Without Pre-lab	50	14	20	12	26	28
Q1 (m)	*For this experiment it was easy to use the apparatus*					
With Pre-lab	56	34	28	13	13	12
Without Pre-lab	50	14	16	12	30	28
Q1 (n)	*I successfully completed this experiment within the prescribed time*					
With Pre-lab	56	45	30	11	14	0
Without Pre-lab	50	28	22	10	26	14
Q1 (o)	*I need more information on how to prepare for this experiment*					
With Pre-lab	56	7	11	11	34	37
Without Pre-lab	50	30	32	12	14	12
Q1 (p)	*Experimental procedure was more clear due to my preparation*					
With Pre-lab	56	32	32	13	12	11
Without Pre-lab	50	12	12	10	32	34
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*					
With Pre-lab	56	34	28	9	13	16
Without Pre-lab	50	12	12	10	32	34
Q1 (r)	*The experiment helped me to understand some of the course work*					
With Pre-lab	56	47	23	11	10	9
Without Pre-lab	50	10	10	14	32	34
Q1 (s)	*The procedure was not clearly explained in the lab manual*					
With Pre-lab	56	9	9	11	34	37
Without Pre-lab	50	28	26	12	20	14
Q1 (t)	*Not enough time was given to complete the experiment*					
With Pre-lab	56	0	13	11	31	45
Without Pre-lab	50	14	26	10	22	28

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question two:

Group	**N**		%						
With Pre-lab	56	*Useful*	45	32	9	7	7	0	*Not useful*
Without Pre-lab	50		20	22	12	14	18	14	
With Pre-lab	56	*Helpful*	25	43	11	10	11	0	*Not helpful*
Without Pre-lab	50		18	20	12	20	16	14	
With Pre-lab	56	*Meaningful*	16	43	13	10	7	11	*Not meaningful*
Without Pre-lab	50		18	16	12	16	20	18	
With Pre-lab	56	*Understandable*	29	37	13	10	4	7	*Not understandable*
Without Pre-lab	50		12	12	14	16	24	22	
With Pre-lab	56	*Satisfying*	26	32	16	11	6	9	*Not satisfying*
Without Pre-lab	50		16	14	14	18	20	18	
With Pre-lab	56	*Interesting*	34	29	11	12	14	0	*Boring*
Without Pre-lab	50		18	18	16	18	16	14	
With Pre-lab	56	*Well-organised*	23	36	12	11	9	9	*Not well-organised*
Without Pre-lab	50		22	18	12	14	18	16	

Responses for question three:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q3 (a)	*I found discussions boring.*					
With Pre-lab	56	22	23	2	28	25
Without Pre-lab	50	16	16	10	32	26
Q3 (b)	*I enjoyed working with members of my group.*					
With Pre-lab	56	27	32	0	23	18
Without Pre-lab	50	32	36	10	10	12
Q3 (c)	*Most of the ideas were not helpful.*					
With Pre-lab	56	15	23	5	27	30
Without Pre-lab	50	12	12	10	34	32
Q3 (d)	*Most of the ideas came from one person.*					
With Pre-lab	56	11	10	11	38	30
Without Pre-lab	50	12	10	10	34	34
Q3 (e)	*Working as a group made it easier for us to get answers.*					
With Pre-lab	56	29	25	14	16	16
Without Pre-lab	50	36	30	12	10	12
Q3 (f)	*I did not respect ideas from others since they are always wrong.*					
With Pre-lab	56	20	16	5	30	29
Without Pre-lab	50	14	12	12	32	30

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

C.3 Experiment 3: Determination of wavelength of light from the helium neon laser

C.3.1 Pre-Lab

You should read the Pre-Lab sheet before you come to the lab. The staff in the laboratory are going to check if you did or not.

What should I know before I begin?

- You should be familiar with the principles of the operation of a laser.
- The characteristics of laser light which make it suitable for this experiment.
- You should be sufficiently familiar with the ideas of diffraction interference to understand the experiment.
- Remove watches bracelets, rings and other jewelry that might reflect the laser light.
- Under any circumstances:
  1. Do not look directly into the laser beam at any time.
  2. Do not shine the laser towards anyone.
  3. Do not shine reflected laser light towards anyone.

What does laser do?

The unique characteristics of light produced by laser make it suitable for many applications, for example:

- Precision length measurement.
- Medical.
- Drilling.
- Tracking.
- Welding.

- Velocity measurement.
- Cutting.

Why measure laser wavelength in this practical?

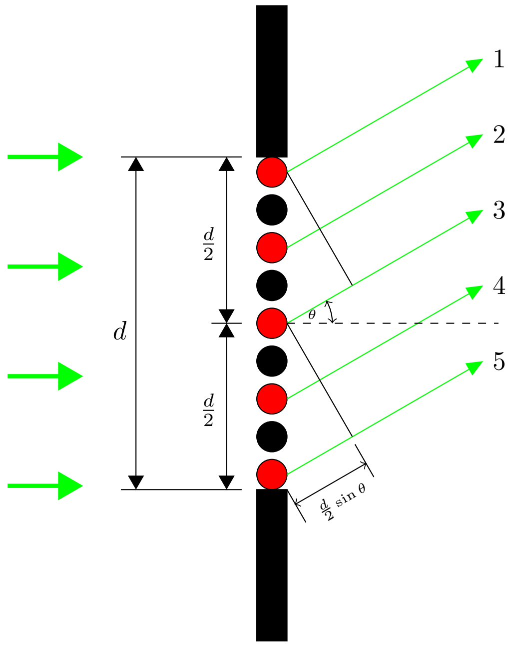
Laser light contains only one wavelength which results in very sharp diffraction patterns. Other sources emit a range of wavelengths resulting in a blur of overlapping patterns. This characteristic of laser light makes it ideal for the experimental study of diffraction phenomena.

What is the point of this experiment?

You are going to use diffraction grating to measure the wavelength of laser light, diffraction grating consists of a large number of fine, evenly spaced parallel slits, the condition required for a diffraction grating to produce bright frings is the same as for double-slit setup

$$d \sin\theta = m\,\lambda$$

Where m is the order number, $m = 0, 1, 2, 3 \ldots\ldots$, $\lambda =$ wavelength and $d =$ distance between lines (slit width). As seen in the graph.



What is the experiment about?

You will determine the laser's wavelength by using diffraction grating. Read the description in the manual, also see the book :(Alfezia Altjrebia, "Practical physivs by Mohamed Sallem Aleed"

What is the experiment about?

You will determine the laser's wavelength by using diffraction grating. Read the description in the manual, also see the book: (Alfezia Altjrebia, "Practical physics" by Mohamed Salem,(2000) الفيزياء التجريبية لمحمدسالم)

What will I be doing?

Read the description in the manual, also see the book: (Alfezia Altjrebia, "Practical physics" by Mohamed Salem,(2000) الفيزياء التجريبية لمحمد سالم) and answer these questions:

1. What are the laser beam properties?
2. Which type of laser do you use?
3. What is the definition of diffraction?

C.3.2 Instruction Sheet

Objective:

Determination of wavelength of a helium neon laser by using diffraction grating.

Apparatus:

Diffraction grating, helium neon laser source, screen and meter scale ruler.

Theory:

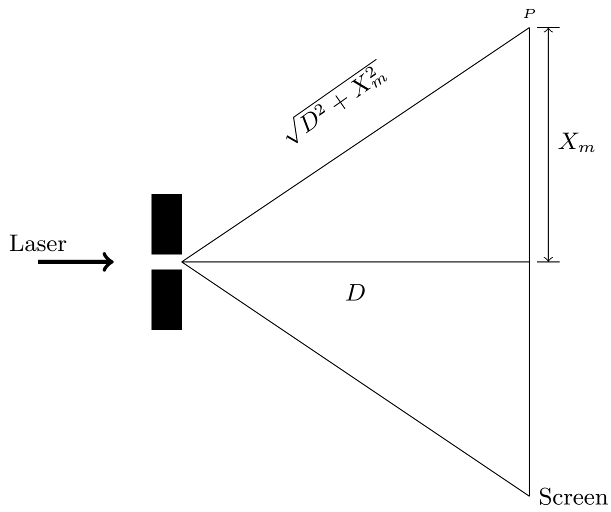
A diffraction grating consists of a large number of fine, evenly spaced parallel slits. It has 5,000 to 6,000 lines per cm; the exact number is written on the grating. When a laser beam is directed to a diffraction grating, an interference pattern can be observed on a screen, then the central maximum will be observed with several maxima on both sides. From the figure below, θ is the angle of diffraction, d is the grating spacing, or distance between the centre of adjacent slits, λ is the wavelength of the light used, m is the order of the spectrum, then:

$$\frac{m}{\lambda} d = \sin\theta$$

Or

$$m\,\lambda = d\,\sin\theta \tag{C.7}$$

That is the condition of the waves from the various slits constructively interferes with each other. And the wavelength can be calculated by equation number C.7.



Procedures:

1. Keep the laser beam horizontal and switch it on, put the diffraction grating normal to the neon laser beam, this could be done by adjusting the grating in such way that the reflected laser beam coincides with the beam coming out of the laser source.
2. Observe the diffraction pattern, and the diffraction laser spots are seen.
3. Measure the distance X_m on the screen between the m^{th} and 0^{th} order image, the measuring will be from both sides, then take the average of them, Where $m = 1, 2, 3, \ldots\ldots$
4. Calculate $\sin\theta$ from the relation: $\dfrac{X_m}{(D^2 + X_m^2)^{1/2}}$ Substitute the value of $\sin\theta$ in the equation: $m\,\lambda = d\,\sin\theta$ then $\lambda = \dfrac{d\,\sin\theta}{m}$ where d is the separation of the slit.
5. Repeat step (4) for $m = 2, 3, 4, \ldots\ldots$ and in each time calculate λ.

Observations:

Distance between the grating and the screen $D = \ldots\ldots\ldots m.$

Number of lines in the grating per metres $= \ldots\ldots\ldots$ lines per metre.

Obs. no.	Order of Diffraction (m)	Reading for Diffraction image						Mean θ	λ
		Left side			Right Side				
		(X_m)	$\tan\theta = \frac{X_m}{D}$	θ	(X_m)	$\tan\theta = \frac{X_m}{D}$	θ		
1		X_1			X_1				
2		X_2			X_2				
3		X_3			X_3				

Result:

The wave length of the helium neon laser $\lambda = \ldots\ldots\ldots nm = \ldots\ldots A^{\circ}$

Precaution:

- You should ensure that you do not look directly in the laser beam.
- Do not shine the laser towards anyone.
- Do not shine the reflected laser light towards anyone.
- Remove watches bracelets, rings and other jewelry that might reflect the laser light.

for more information about this experiment(see Alfezia Altjrebia, “Practical physics” by Mohamed Salem, (2000) الفيزياء التجريبية لمحمد سالم

C.3.3 Post-lab

This test seeks to test your ability to understand some ideas in optics. The marks from this test will not affect your university grades in any way. Most of the answers can be shown by writing a number or ticking a box.

See the table below:

a- Single slit	b- Multiple slit
c- Double slit	d- Diffraction Grating

1. Chose the answer from the above table: If we need to separate light of different wavelength with high resolution, which tool is the best choice

   ....

2. When 675 nm light passes through diffraction grating, a second-order principle maximum is observed at an angle of 20°. Which mathematical formula should you use to calculate the number of slits per centimetre for this grating?
   (a) $d\,\sin\theta = m\,\lambda$
   (b) $d\,\sin\theta = (m/2)\,\lambda$
   (c) $(d/2)\,\sin\theta = m\lambda$

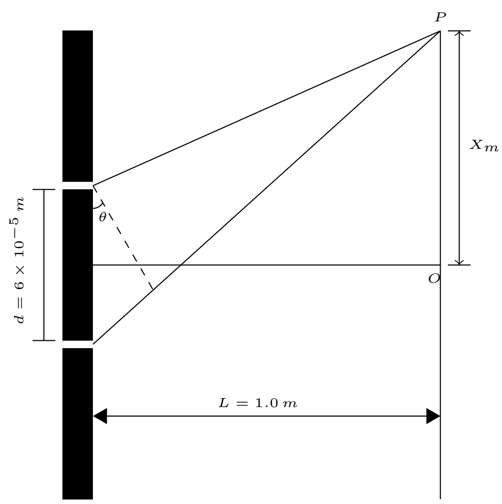
3. Explain why the light from the two headlights of a distant car does not produce an interference pattern.

   ....

   ....

4. Select from below one statement which refers to the increasing of the number of slits makes the diffraction
   (a) The diffraction maximum sharper and also more intense.
   (b) The diffraction maximum sharper but less intense.
   (c) The diffraction minimum sharper and also less intense.
   (d) No difference.
   (e) The diffraction minimum sharper but more intense.
   (f) The diffraction maximum sharper but no affect on intense.

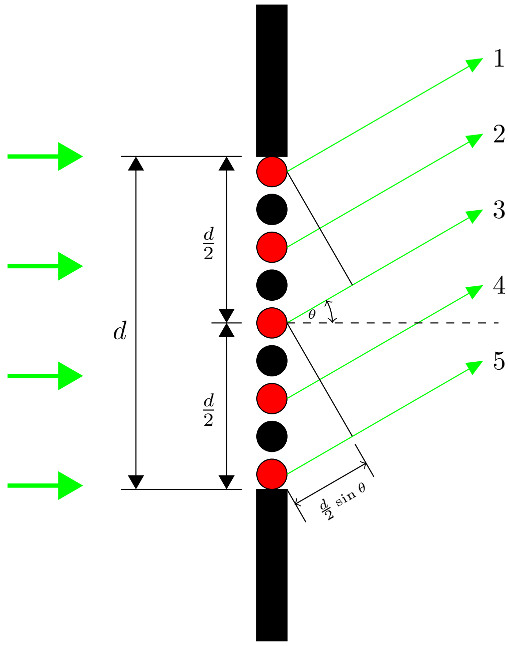
5. Select from below one answer which refer to the light which we should use to produce hologram:
   (a) Any source of light.
   (b) Monochromatic light only.
   (c) White light only.
   (d) Laser beam only.
6. Select the correct answer:
   In order to form an interference pattern, the incident light must be:
   (a) Coherent.
   (b) Monochromatic.
   (c) Incoherent.
   (d) Any source.
7. The condition for maximum intensity for diffraction grating is the same as for double slit or different?
   ....
8. Opinions differ when it comes to like/dislike sunset view, however, opinion do not differ for the physical phenomenon attributable to this view which is seen as reddish-orange colour, this phenomenon is:
   (a) Polarisation.
   (b) Diffraction.
   (c) Dispersion.
   (d) Refraction.
9. What is the colour of monochromatic light source if the distance to the second order bright fringe is 20 millimetre? and the slit width equal to 6.0 $\times$ $10^{-5}\,m$.



a) Blue. b) Green. c) Orange.

10. The light passing through this slit when seen on the screen far from the slit will exhibit destructive interference when:

a) $\frac{a}{2}\sin\theta = \frac{\lambda}{4}$ b) $\frac{a}{2}\sin\theta = \frac{\lambda}{2}$ c) $\frac{a}{2}\sin\theta = \lambda$



C.3.4 Data from Questionnaire used after Third Experiment

See D.2 for the original question. Responses for question one, part one:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (a)	*This experiment was easy to do*					
With Pre-lab	50	32	32	12	12	12
Without Pre-lab	56	21	22	11	25	21
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*					
With Pre-lab	50	40	30	10	12	8
Without Pre-lab	56	23	20	11	26	20
Q1 (c)	*Preparation for the lab was not very helpful in following the experimental procedure*					
With Pre-lab	50	8	10	16	36	30
Without Pre-lab	56	28	23	13	20	16
Q1 (d)	*Having done this experiment I now find the topic more interesting*					
With Pre-lab	50	34	34	10	12	10
Without Pre-lab	56	14	20	11	30	25
Q1 (e)	*I found this experiment was difficult*					
With Pre-lab	50	10	14	12	32	32
Without Pre-lab	56	21	23	13	22	21
Q1 (f)	*When I started this experiment, I didn't know what its purpose was*					
With Pre-lab	50	8	12	10	32	38
Without Pre-lab	56	21	25	11	20	23
Q1 (g)	*Apparatus used in this experiment was difficult to handle*					
With Pre-lab	50	12	14	8	34	32
Without Pre-lab	56	21	23	13	23	20
Q1 (h)	*Preparation for this experiment not contributed to my understanding of the course*					
With Pre-lab	50	10	12	12	26	40
Without Pre-lab	56	12	24	14	21	29
Q1 (i)	*I could not do a similar experiment on my own without further instruction*					
With Pre-lab	50	8	12	18	36	26
Without Pre-lab	56	18	16	11	28	27
Q1 (j)	*My preparation for this experiment made me not interested in the subject.*					
With Pre-lab	50	10	12	10	36	32
Without Pre-lab	56	25	30	11	20	14

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question one, part two:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*					
With Pre-lab	50	30	34	10	14	12
Without Pre-lab	56	11	12	13	30	34
Q1 (l)	*It was easy to follow the laboratory manual*					
With Pre-lab	50	30	36	8	16	10
Without Pre-lab	56	20	23	13	23	21
Q1 (m)	*For this experiment it was easy to use the apparatus*					
With Pre-lab	50	38	26	8	14	14
Without Pre-lab	56	22	21	13	21	23
Q1 (n)	*I successfully completed this experiment within the prescribed time*					
With Pre-lab	50	36	40	4	12	8
Without Pre-lab	56	30	32	13	14	11
Q1 (o)	*I need more information on how to prepare for this experiment*					
With Pre-lab	50	12	12	10	34	32
Without Pre-lab	56	34	30	13	12	11
Q1 (p)	*Experimental procedure was more clear due to my preparation*					
With Pre-lab	50	30	36	16	12	6
Without Pre-lab	56	16	20	11	25	28
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*					
With Pre-lab	50	26	36	18	10	10
Without Pre-lab	56	18	16	11	28	27
Q1 (r)	*The experiment helped me to understand some of the course work*					
With Pre-lab	50	40	28	10	12	10
Without Pre-lab	56	14	22	14	21	29
Q1 (s)	*The procedure was not clearly explained in the lab manual*					
With Pre-lab	50	12	14	8	30	36
Without Pre-lab	56	21	23	13	23	20
Q1 (t)	*Not enough time was given to complete the experiment*					
With Pre-lab	50	10	10	4	40	36
Without Pre-lab	56	13	12	13	32	30

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question two:

Group	**N**		%						
With Pre-lab	50	*Useful*	30	30	16	12	8	4	*Not useful*
Without Pre-lab	56		30	20	11	14	13	12	
With Pre-lab	50	*Helpful*	32	34	12	14	6	2	*Not helpful*
Without Pre-lab	56		18	16	12	18	13	23	
With Pre-lab	50	*Meaningful*	30	30	10	12	10	8	*Not meaningful*
Without Pre-lab	56		13	16	20	12	20	19	
With Pre-lab	50	*Understandable*	38	36	4	6	10	6	*Not understandable*
Without Pre-lab	56		13	12	11	12	20	32	
With Pre-lab	50	*Satisfying*	26	34	14	18	8	0	*Not satisfying*
Without Pre-lab	56		13	12	11	12	20	32	
With Pre-lab	50	*Interesting*	24	34	16	6	12	8	*Boring*
Without Pre-lab	56		13	17	16	14	20	20	
With Pre-lab	50	*Well-organised*	22	36	16	6	8	12	*Not well-organised*
Without Pre-lab	56		11	10	13	12	29	25	

Responses for question three:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q3 (a)	*I found discussions boring.*					
With Pre-lab	50	22	18	0	38	22
Without Pre-lab	56	16	13	14	29	28
Q3 (b)	*I enjoyed working with members of my group.*					
With Pre-lab	50	26	32	0	26	16
Without Pre-lab	56	28	26	13	14	18
Q3 (c)	*Most of the ideas were not helpful.*					
With Pre-lab	50	16	14	12	30	28
Without Pre-lab	56	13	19	11	27	30
Q3 (d)	*Most of the ideas came from one person.*					
With Pre-lab	50	14	16	16	24	30
Without Pre-lab	56	13	14	12	29	32
Q3 (e)	*Working as a group made it easier for us to get answers.*					
With Pre-lab	50	24	34	14	14	14
Without Pre-lab	56	30	34	13	11	12
Q3 (f)	*I did not respect ideas from others since they are always wrong.*					
With Pre-lab	50	16	16	12	26	30
Without Pre-lab	56	11	12	13	30	34

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

C.4 Experiment 4: Rotation of plane of polarisation with sugar solutions

C.4.1 Pre-Lab

You should read the Pre-Lab sheet before you come to the lab. The staff in the lab will check if you did or not.

What should I know before I begin?

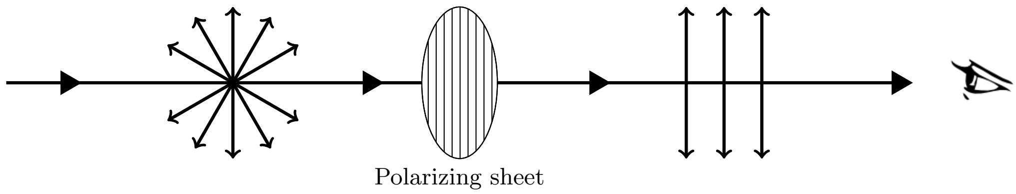
You should know:

- You should be familiar with the phenomena of polarisation.
- What is the optical activity.
- How to use polarimeter.
- What is the angle of rotation.

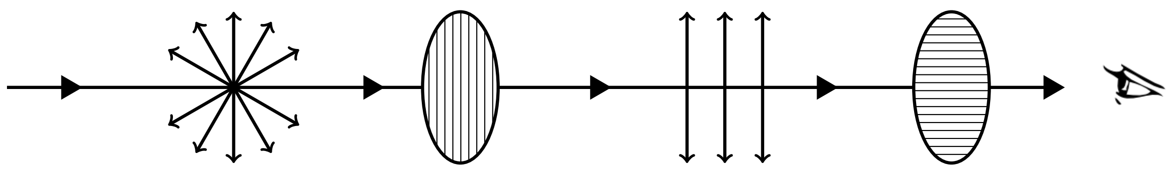
After you know the above please answer this question:

- What are the types of polarisation?

Ideas of Polarisation by figures:



A polarised sheet produces plane-polarised light from unpolarised light, and the parallel lines which are not actually visible on the sheet, suggest the characteristic polarising direction of the sheet.



In the figure above,unpolarised light is not transmitted by crossed polarising sheets.

What does a polarimeter do?

Polarimeter is an instrument for measuring the state of polarisation of a beam of light or other form of electromagnetic radiation. It is designed to detect and measure the rotation of plane-polarised light. The rotation is directly proportional to the number of optically active molecules in the path of the light. If the sample tube is long, there will be many molecules, and the rotation will be large. Similarly, if the concentration of the sample is high, there will also be many molecules, and the rotation will be large.

Mathematically the relationship for optical rotation is $[\alpha] = \dfrac{\theta}{cl}$

Where l is the length of the tube in decimetres (dm) and c is the concentration of the solution in g/ml. θ is the angle of optical rotation, The specific rotation, α is the specific rotation.

What is the experiment about?

This experiment about the phenomena of Optical activity which is a property of several substances by which the plane of polarisation of linearly polarised light is rotated on passing through the substance. This phenomenon occurs, among other things, in some solutions. Here the molecular structure of the dissolved substance leads to right-circularly and left-circularly polarised light propagating at different phase velocities in the solution. Linearly polarised light which enters the solution can be decomposed into a right-circularly and a left-circularly polarised partial wave. The two partial waves propagate at different phase velocities so that a phase difference arises, which is proportional to the distance covered. After the two partial waves have covered this distance, their superposition results in a linearly polarised wave whose direction of polarisation is rotated relative to the original.

What will I measure?

- You will observe the rotation of the plane of polarisation by concentrated sugar solution in an arrangement of two crossed polarisers.
- You will determine the angle of rotation of the plane of polarisation with sugar solution.

for more information about this experiment(see Alfezia Altjrebia, “Practical physics” by Mohamed Salem, (2000) الفيزياء التجريبية لمحمد سالم

C.4.2 Instruction Sheet

Objective:

To measure the specific rotation of sugar solution by using a polarimeter.

Apparatus:

Polarimeter, distil water, balance, sodium lamb, beaker, sugar, polariser (Nicol prism) [Polarimeter: a tube with flat glass ends]

Theory:

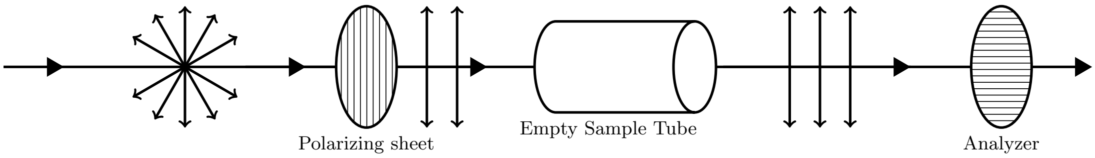
Optical activity is a property of several substances by which the plane of polarisation of linearly polarised light is rotated on passing through the substance. This phenomenon occurs, among other things, in some solutions. Here the molecular structure of the dissolved substance leads to right-circularly and left-circularly polarised light propagating at different phase velocities in the solution. Linearly polarised light which enters the solution can be decomposed into a right-circularly and a left-circularly polarised partial wave. The two partial waves propagate at different phase velocities so that a phase difference arises, which is proportional to the distance covered. After the two partial waves have covered this distance, their superposition results in a linearly polarised wave whose direction of polarisation is rotated relative to the original wave. Specific rotation is the observed angle of optical rotation θ when plane-polarised light is passed through a sample with a path length of 1 decimetre and a sample concentration of 1 gram per 1 millilitre. Then the specific rotation α depends upon these variable:

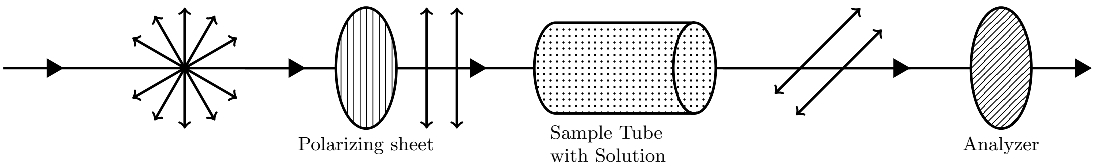
- The wavelength of the light source.
- Temperature of the sample.
- The type of the nature of sample.
- The concentration of the optical active components.
- The length of the light tube.

Mathematically the relationship for optical rotation is:

$$[\alpha] = \frac{\theta}{c\,l}$$

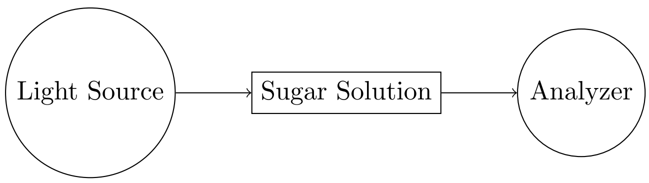
Where l is the length of the tube in decimetres (dm) and c is the concentration of the solution in g/mL. θ is the angle of optical rotation, $[\alpha]$ is the specific rotation.





Procedure:

1. Mount the instrument in the order shown in the below figure.



2. Clean the polarimeter tube from both sides to be clean from any dust.
3. Fill the tube with pure water, see carefully that there is no bubble enclosed in it, and place it in its position inside the polarimeter.
4. Switch on the source of light and look through the eyepiece. Rotate the analyser until two halves of field appears equally bright, then take the reading of the main scale as well as vernier scale and find out the total reading.

5. Fill the tube with known strength sugar solution, again place it in the polarimeter.
6. Rotate the analyser to obtain the equal intensity position, first in clockwise direction and also in anti-clockwise direction.
7. Find the main reading and calculate the difference between this and the reading from pure water reading, this difference is the specific rotation.
8. Fill the tube with different sugar solution of different concentrations, and repeat taking readings like above.
9. Measure the length of the tube.

Observation:

Part one:

1. Mass of glass of the tube = ... gm
2. Length of polarimeter tube l = ... $decimeter$
3. Room temperature = ... C°

Part two:

- Value of one division of the main scale = ...
- No. of division of vernier scale = ...
- Least count of vernier = ...

Reading with pure water		Mean a	Conc. of Solution	Reading with sugar solution		Mean b	θ
Clockwise	Anti-clockwise			Clockwise	Anti-clockwise		
Total X	Total Y			Total X'	Total Y'		
			1 2 3				

Where $\theta = a - b$

Concentration in $gm/c.c$

Calculation:

Plot the graph between θ and concentrations of solution; from the slope of the line you will calculate the specific rotation of sugar solution by using this equation:$[\alpha] = \frac{\theta}{c\,l}$ Where $\frac{\theta}{c}$ represented the slope of the line, and l is the length of the tube.

for more information about this experiment(see Alfezia Altjrebia, “Practical physics” by Mohamed Salem, (2000) الفيزياء التجريبية لمحمد سالم

C.4.3 Post-lab

This test seeks to test your ability to understand some ideas in optics. The marks from this test will not affect your university grades in any way. Most of the answers can be shown by writing a number or ticking a box.

1. Look at the table below.

a- Diffracted	b- Transverse	c- Unpolarised
d- Interfering	e- None of them	f- Polarised

   (a) Select the box or boxes which refer to the light which is vibrating in a single plane.........

   (b) Select the box or boxes which refer to the light which is vibrating in a variety of planes.........

2. Look at the statements below.

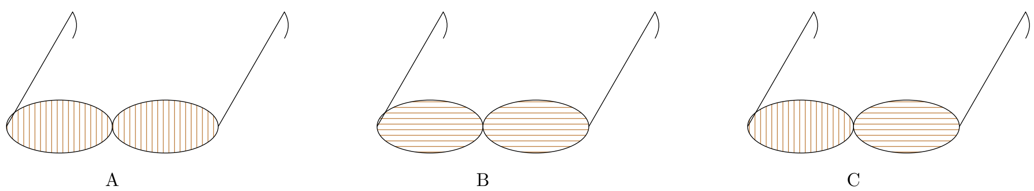
a- The type or nature of sample	b- The wavelength of the light source
c- The length of the sample tube	d- Temperature of the sample
e- Concentration of the optical active components	

   Now think of a polarisation:

   (a) Select the box or boxes which refer to factors which will affect the observed rotation.........,.........

   (b) Select the box or boxes which refer to factors which will affect the specific rotation.........,.........

3. Look carefully to these sunglasses, could you chose one which are capable to eliminate the glare from a road surface(The polarisation axes are shown by the straight lines) ....



4. Explain in your own words the meaning of the term 'optical activity'

   ....

   ....

   ....

5. Light is passed through a polaroid filter whose transmission axis is aligned horizontally. Choose the answer which shows the effect of this.
   (a) Making the light one-half as intense and aligning the vibrations into a single plane.
   (b) Aligning the vibrations into a single plane without any effect on its intensity.
   (c) Merely making the light one-half as intense; the vibrations would be in every direction.
   (d) This will have no effect on the light itself; only the filter would be effected.
6. Light is passed through a polaroid filter whose transmission axis is aligned horizontally. It then passes through a second filter whose transmission axis is aligned vertically. After passing through both filters, the light will be: (Tick one box)
   (a) Polarised.
   (b) Unpolarised.
   (c) Entirely blocked.
   (d) Returned to its original state.
7. Which of the following are effective methods of polarisation? Tick all that apply.
   (a) Passing light through a polaroid filter.
   (b) Reflection of light off a nonmetallic surface.
   (c) Passing light from water to air.
   (d) Turning the light on and off at a high frequency.
   (e) Interfering light from one source with a second source.

C.4.4 Data from Questionnaire used after Fourth Experiment

See D.2 for the original question. Responses for question one, part one:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (a)	*This experiment was easy to do*					
With Pre-lab	50	34	36	14	8	8
Without Pre-lab	56	14	20	16	25	25
Q1 (b)	*The purpose of this experiment was very clear to me when I started the lab work*					
With Pre-lab	50	30	42	12	12	4
Without Pre-lab	56	13	16	12	30	29
Q1 (c)	*Preparation for the lab was not very helpful in following the experimental procedure*					
With Pre-lab	50	6	8	14	38	34
Without Pre-lab	56	13	14	12	29	32
Q1 (d)	*Having done this experiment I now find the topic more interesting*					
With Pre-lab	50	34	36	6	18	6
Without Pre-lab	56	21	20	11	23	25
Q1 (e)	*I found this experiment was difficult*					
With Pre-lab	50	10	6	14	34	36
Without Pre-lab	56	27	23	16	20	14
Q1 (f)	*When I started this experiment, I didn't know what its purpose was*					
With Pre-lab	50	4	14	10	42	30
Without Pre-lab	56	29	30	14	14	13
Q1 (g)	*Apparatus used in this experiment was difficult to handle*					
With Pre-lab	50	8	12	12	34	34
Without Pre-lab	56	14	13	18	29	26
Q1 (h)	*Preparation for this experiment not contributed to my understanding of the course*					
With Pre-lab	50	8	10	10	40	32
Without Pre-lab	56	36	25	11	14	14
Q1 (i)	*I could not do a similar experiment on my own without further instruction*					
With Pre-lab	50	14	6	8	30	42
Without Pre-lab	56	24	23	13	18	22
Q1 (j)	*My preparation for this experiment made me not interested in the subject.*					
With Pre-lab	50	8	16	6	34	36
Without Pre-lab	56	25	23	11	20	21

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question one, part two:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q1 (k)	*The preparation I did before coming to the laboratory was enough, and helped me to understand what I was doing*					
With Pre-lab	50	42	26	10	6	16
Without Pre-lab	56	16	14	16	29	25
Q1 (l)	*It was easy to follow the laboratory manual*					
With Pre-lab	50	32	32	14	18	4
Without Pre-lab	56	16	23	14	25	22
Q1 (m)	*For this experiment it was easy to use the apparatus*					
With Pre-lab	50	34	34	12	14	6
Without Pre-lab	56	14	13	18	27	28
Q1 (n)	*I successfully completed this experiment within the prescribed time*					
With Pre-lab	50	42	32	10	8	8
Without Pre-lab	56	25	29	14	14	18
Q1 (o)	*I need more information on how to prepare for this experiment*					
With Pre-lab	50	16	10	8	26	40
Without Pre-lab	56	25	29	16	14	16
Q1 (p)	*Experimental procedure was more clear due to my preparation*					
With Pre-lab	50	34	36	16	10	4
Without Pre-lab	56	13	14	12	31	30
Q1 (q)	*Having done this experiment, I can see how to apply my knowledge in other contexts*					
With Pre-lab	50	42	32	6	6	14
Without Pre-lab	56	20	20	13	23	24
Q1 (r)	*The experiment helped me to understand some of the course work*					
With Pre-lab	50	36	38	10	10	6
Without Pre-lab	56	14	14	11	25	36
Q1 (s)	*The procedure was not clearly explained in the lab manual*					
With Pre-lab	50	6	16	14	32	32
Without Pre-lab	56	22	25	14	21	18
Q1 (t)	*Not enough time was given to complete the experiment*					
With Pre-lab	50	8	8	10	32	42
Without Pre-lab	56	16	16	16	27	25

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Responses for question two:

Group	N		%						
With Pre-lab	50	*Useful*	40	36	8	8	4	4	*Not useful*
Without Pre-lab	56		27	16	13	14	16	14	
With Pre-lab	50	*Helpful*	36	34	10	6	6	8	*Not helpful*
Without Pre-lab	56		25	18	14	15	17	11	
With Pre-lab	50	*Meaningful*	30	30	18	10	4	8	*Not meaningful*
Without Pre-lab	56		20	23	18	12	11	16	
With Pre-lab	50	*Understandable*	38	34	6	6	8	8	*Not understandable*
Without Pre-lab	56		25	20	21	11	12	11	
With Pre-lab	50	*Satisfying*	26	32	12	14	12	4	*Not satisfying*
Without Pre-lab	56		18	18	16	14	21	13	
With Pre-lab	50	*Interesting*	30	28	14	12	6	10	*Boring*
Without Pre-lab	56		16	18	22	14	20	10	
With Pre-lab	50	*Well-organised*	10	20	22	16	14	18	*Not well-organised*
Without Pre-lab	56		13	10	14	18	23	22	

Responses for question three:

		%				
Group	**N**	**S. Agree**	**Agree**	**Not Sure**	**Disagree**	**S. Disagree**
Q3 (a)	*I found discussions boring.*					
With Pre-lab	50	20	20	0	26	34
Without Pre-lab	56	23	27	16	18	16
Q3 (b)	*I enjoyed working with members of my group.*					
With Pre-lab	50	26	36	0	16	22
Without Pre-lab	56	25	13	14	23	25
Q3 (c)	*Most of the ideas were not helpful.*					
With Pre-lab	50	20	18	12	24	26
Without Pre-lab	56	25	18	11	23	23
Q3 (d)	*Most of the ideas came from one person.*					
With Pre-lab	50	20	18	14	26	22
Without Pre-lab	56	17	16	14	23	29
Q3 (e)	*Working as a group made it easier for us to get answers.*					
With Pre-lab	50	24	28	18	16	14
Without Pre-lab	56	23	21	16	20	19
Q3 (f)	*I did not respect ideas from others since they are always wrong.*					
With Pre-lab	50	16	16	22	22	24
Without Pre-lab	56	20	19	14	20	27

Legend	
N	Number of students
S. Agree	Strongly Agree
S. Disagree	Strongly Disagree

Appendix D

Questionnaires

D.1 2nd Stage Questionnaire

This work is seeking information about reaction to the experiment you have just completed. Your response will not affect your assessment in any way. Please tick the appropriate box to indicate the extent which you agree or disagree with each of the following.

Practical Evaluation

Name of Experiment………… Student Number…………

Q1. Tick the appropriate box to indicate the extent which you agree or disagree with each of the following statements:

	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
(a)	This experiment was easy to do.	☐	☐	☐	☐	☐
(b)	The purpose of this experiment was very clear to me when I started the lab work.	☐	☐	☐	☐	☐
(c)	Preparation for the lab was not very helpful in following the experimental procedure.	☐	☐	☐	☐	☐
(d)	Having done this experiment I now find the topic more interest.	☐	☐	☐	☐	☐
(e)	I found this experiment was difficult.	☐	☐	☐	☐	☐
(f)	When I started this experiment, I didn't know what it's purpose was.	☐	☐	☐	☐	☐
(g)	Apparatus used in this experiment was difficult to handle.	☐	☐	☐	☐	☐
(h)	Preparation for this experiment not contributed to my understanding of the course.	☐	☐	☐	☐	☐
(i)	I could not do a similar experiment on my own without further instruction.	☐	☐	☐	☐	☐
(j)	My preparation for this experiment made me not interested in the subject.	☐	☐	☐	☐	☐
(k)	The preparation I did before coming to the lab was enough, and helped me to understand what I was going.	☐	☐	☐	☐	☐
(l)	It was easy to follow the lab. manual.	☐	☐	☐	☐	☐
(m)	For this experiment it was easy to use the apparatus.	☐	☐	☐	☐	☐
(n)	I successfully completed this experiment within the prescribed time.	☐	☐	☐	☐	☐
(o)	I need more information on how to prepare for this experiment.	☐	☐	☐	☐	☐
(p)	Experimental procedure was much clear due to my preparation.	☐	☐	☐	☐	☐
(q)	Having done this experiment, I can see how to apply my knowledge in other contexts.	☐	☐	☐	☐	☐
(r)	The experiment helped me to understand some of the course work.	☐	☐	☐	☐	☐
(s)	The procedure was not clearly explained in the lab manual.	☐	☐	☐	☐	☐
(t)	Not enough time was given to complete the experiment.	☐	☐	☐	☐	☐

Here is a way to describe a racing car.

quick	☑	☐	☐	☐	☐	☐	slow
important	☐	☐	☑	☐	☐	☐	unimportant
safe	☐	☐	☐	☐	☑	☐	dangerous

The positions of the ticks between the word pairs show that you consider it as very quick, slightly more important than unimportant and quite dangerous.

Q2. What are your opinions about your experiment?

(Tick ONE box on each line)

Useful	☐	☐	☐	☐	☐	☐	Useless
Helpful	☐	☐	☐	☐	☐	☐	Not helpful
Meaningful	☐	☐	☐	☐	☐	☐	Not meaningful
Understandable	☐	☐	☐	☐	☐	☐	Not understandable
Satisfying	☐	☐	☐	☐	☐	☐	Not Satisfying
Interesting	☐	☐	☐	☐	☐	☐	Not interesting
Well-Organised	☐	☐	☐	☐	☐	☐	Not well-Organised

D.2 3rd Stage Questionnaire

This work is seeking information about reaction to the experiment you have just completed. Your response will not affect your assessment in any way. Please tick the appropriate box to indicate the extent which you agree or disagree with each of the following.

Practical Evaluation

Name of Experiment………… Student Number…………

Q1. Tick the appropriate box to indicate the extent which you agree or disagree with each of the following statements:

	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
(a)	This experiment was easy to do.	☐	☐	☐	☐	☐
(b)	The purpose of this experiment was very clear to me when I started the lab work.	☐	☐	☐	☐	☐
(c)	Preparation for the lab was not very helpful in following the experimental procedure.	☐	☐	☐	☐	☐
(d)	Having done this experiment I now find the topic more interest.	☐	☐	☐	☐	☐
(e)	I found this experiment was difficult.	☐	☐	☐	☐	☐
(f)	When I started this experiment, I didn't know what it's purpose was.	☐	☐	☐	☐	☐
(g)	Apparatus used in this experiment was difficult to handle.	☐	☐	☐	☐	☐
(h)	Preparation for this experiment not contributed to my understanding of the course.	☐	☐	☐	☐	☐
(i)	I could not do a similar experiment on my own without further instruction.	☐	☐	☐	☐	☐
(j)	My preparation for this experiment made me not interested in the subject.	☐	☐	☐	☐	☐
(k)	The preparation I did before coming to the lab was enough, and helped me to understand what I was going.	☐	☐	☐	☐	☐
(l)	It was easy to follow the lab. manual.	☐	☐	☐	☐	☐
(m)	For this experiment it was easy to use the apparatus.	☐	☐	☐	☐	☐
(n)	I successfully completed this experiment within the prescribed time.	☐	☐	☐	☐	☐
(o)	I need more information on how to prepare for this experiment.	☐	☐	☐	☐	☐
(p)	Experimental procedure was much clear due to my preparation.	☐	☐	☐	☐	☐
(q)	Having done this experiment, I can see how to apply my knowledge in other contexts.	☐	☐	☐	☐	☐
(r)	The experiment helped me to understand some of the course work.	☐	☐	☐	☐	☐
(s)	The procedure was not clearly explained in the lab manual.	☐	☐	☐	☐	☐
(t)	Not enough time was given to complete the experiment.	☐	☐	☐	☐	☐

Here is a way to describe a racing car.

quick	☑	☐	☐	☐	☐	☐	slow	
important	☐	☐	☑	☐	☐	☐	unimportant	
safe	☐	☐	☐	☐	☑	☐	dangerous	

The positions of the ticks between the word pairs show that you consider it as very quick, slightly more important than unimportant and quite dangerous.

Q2. What are your opinions about your experiment?

(Tick ONE box on each line)

Useful	☐	☐	☐	☐	☐	☐	Useless
Helpful	☐	☐	☐	☐	☐	☐	Not helpful
Meaningful	☐	☐	☐	☐	☐	☐	Not meaningful
Understandable	☐	☐	☐	☐	☐	☐	Not understandable
Satisfying	☐	☐	☐	☐	☐	☐	Not Satisfying
Interesting	☐	☐	☐	☐	☐	☐	Not interesting
Well-Organised	☐	☐	☐	☐	☐	☐	Not well-Organised

Q3. Tick the appropriate box to indicate the extent which you agree or disagree with each of the following statements:

	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
(a)	I found discussions boring.	☐	☐	☐	☐	☐
(b)	I enjoyed working with members of my group.	☐	☐	☐	☐	☐
(c)	Most of the ideas not helpful..	☐	☐	☐	☐	☐
(d)	Most of the ideas came from one person.	☐	☐	☐	☐	☐
(e)	Working as a group made it easier for us to get answers.	☐	☐	☐	☐	☐
(f)	I did not respect ideas from others since they are always wrong.	☐	☐	☐	☐	☐

Appendix E

Translated Original Instruction Sheet

Objective

To measure the specific rotation of sugar solution by using a polarimeter.

Apparatus

Polarimeter, distil water, balance, sodium lamp, beaker, sugar.

Theory

Previous experiments indicated that liquid has a specific feature of rotation of the plane of polarization which is called *optical active material*.

The molecular structure of the materials is the reason for this phenomenon; each molecule can be considered as a small crystal, when light passes through part of this material each molecule rotates the plane of polarisation by a value which depends on the asymmetry of the distribution of atoms in the molecule. Thus, the angle of rotation depends on the number of molecules in that part of the material which the light passes through and the concentration of the solution.

Specific Rotation

It is defined as the angle of rotation for plane-polarised light when it passes through a solution with a path length of 1 decimetre which contains 1 gram from optical active material for each cubic centimetre. Thus, if θ is the angle of optical rotation, l is the length of the tube, c is the concentration of the solution then:

$$\alpha = \frac{\theta}{c\,l}$$

Brief of the work

Fill the solution which you intend to measure its specific rotation in the tube. Let c be the concentration of the solution in units of grams in each cubic centimetre. when monochromatic light passes through the polarizer, polarized light will come out. Rotate the analyser to be perpendicular on the plane of the polarizer. The field of vision will then be completely dark. By rotating the filled tube with the solution which has a concentration c between the polarizer and analyser. Then the field of vision will be bright.

Procedures

1. Clean the polarimeter tube, and measure its length (dm), fill it with distilled water, and put it in its field.
2. Try to get the two halves of the field to appear equally bright, then take the reading of the main scale as well as the vernier scale and find out the total reading.
3. Prepare the solution with 10% concentration.
4. Fill the polarimeter tube with the solution without any bubbles in the tube, then try to get the two halves of field appears equally bright, and read the scale.
5. The difference between the two reading is the rotation angle.
6. Repeat the previous steps with different concentration.
7. Draw the relation between θ and c to get a straight line, the slope of this line is equal to αl, then you can calculate α.
8. Record you data in the table below:

Concentration C%
θ_c
$\theta = \theta_c - \theta_w$

Where θ_w for distilled water, θ_c for solution, θ for sugar

Appendix F

Chi-square Test (χ^2)

Chi-square test is one of the most widely used tests for statistical data generated by non-parametric analysis. There are two different of application of chi-square test.

Goodness of Fit Test

This study how well the experimental (sampling) distribution fits the control (hypothesised) distribution. An example of this could be a comparison between a group of experimentally observed responses to a group of control responses. For example,

	Positive	Neutral	Negative	
Experimental	25	23	52	N(experimental)=100
Control	50	26	34	N(control)=110
				(using raw number)
A calculation of observed and expected frequencies lead to				
	Positive	Neutral	Negative	
f_o = observed frequency	25	23	52	
f_e = expected frequency	45.45	23.64	30.9	

Where f_e [N (experimental)/N (control)] × or (100/110) × (control data).

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$
$$\chi^2 = \frac{(25 - 45.45)^2}{45.45} + \frac{(23 - 23.64)^2}{23.64} + \frac{(52 - 30.9)^2}{30.9}$$
$$\chi^2 = 23.62$$

The degree of freedom (*df*) for this comparison is 2. This comparison is significant at two degrees of freedom at less than 1% (χ^2 critical at 1% level = 9.21)

Contingency Test

This chi-square test is commonly used in analysing data where two groups or variables are compared. Each of the variables may have two or more categories which are independent from each other. The data for this comparison are generated from the frequencies in the categories. In a study, the chi-square as a contingency test was used, for example, to compare two or more independent samples like, year group, gender, or ages. The data is generated from one population group. For example,

	Positive	Neutral	Negative	
Male (experimental)	11	16	27	
Female (experimental)	13	7	26	
	Positive	Neutral	Negative	N
Male (experimental)	11(12.96)	16(12.42)	27(28.62)	54
Female (experimental)	13(11.04)	7(10.58)	26(24.38)	46
Totals	24	23	53	100

The expected frequencies are shown in brackets( ). are calculated as follows:e.g.12.96 $= (54/100) * 24$

$$\chi^2 = \frac{(11-12.96)^2}{12.96} + \frac{(16-12.42)^2}{12.42} + \frac{(27-28.62)^2}{28.62} + \frac{(13-11.04)^2}{11.04} + \frac{(7-10.58)^2}{10.58} + \frac{(26-24.38)^2}{24.38}$$

$$\chi^2 = 0.296 + 1.03 + 0.092 + 0.35 + 1.21 + 0.12$$

$$\chi^2 = 3.098$$

At two degrees of freedom, this is not significant. (χ^2 critical at 1% level $= 9.21$) The degree of freedom (df) must be stated for any calculated chi-square value. The value of the degree of freedom for any analysis is obtained from the following calculation: $df = (r-1) \times (c-1)$

Where r is the number of rows and c is the number of columns in the contingency table.

Limitation on the Use of χ^2

It is known that when values within a category are small (i.e. 5, as proposed by some writers Wiersma (1995) there is a chance that the calculation of χ^2 may occasionally produce inflated results which may lead to wrong interpretations. In this study, in order to avoid dubious conclusions, a 10% category limit was imposed, and data grouped as necessary (reducing to degree of freedom).

Appendix G

t-test

t-test

The t-test compares the means of two data sets to explore if the data sets are statistically different. The statistic can only be applied to sets of integer data which are approximately normally distributed. Thus, it can be used to compare marks in tests and examinations or the marks obtained by men and women. The specific test used depends on the samples involved. In the study here, the samples are independent samples and the independent samples t-test was used. The t-test is part of the ANOVA group of tests of significance but its used is confined to the comparison between two samples. the equation which used to calculate independent samples t-test is given by Social Science Statistics (2013):

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\left(\frac{(N_1-1)S_1^2 + (N_2-1)S_2^2}{N_1+N_2-2}\right)\left(\frac{1}{N_1}+\frac{1}{N_2}\right)}}$$

Where:

$\overline{x_1}$ = the mean of first data set

$\overline{x_2}$ = the mean of second data set

S_1^2 = the standard deviation of first data set

S_2^2 = the standard deviation of second data set

N_1 = the number of elements in the first data set

N_2 = the number of elements in the secondt data set

Appendix H

Interviews

H.1 Teachers Interviews

Introduction

Get interviewees feel more relaxed and to set them at ease:

(a) Which course do you teach in this semester?
(b) Do you prefer teaching at university or to work in other job, such as work in research centre?
(c) In general, what are the levels of students when they come from school especially in mathematics and physics? (Or is their background in both subject good or not?)
(d) How long have you taught at the university?

Laboratory Physics

Here are the questions about the first theme 'Laboratory physics'

(a) In your opinion, why do you think the students are given practical physics? Or why the syllabus contains practical laboratory?
(b) Laboratory work is regarded as an essential part in understanding physics and any science course. What skills might the laboratory work provide to students?
(c) Do you think the laboratory as we have them now is the right way for practical work to be effective in reaching their goals? If the answer is no, how we could make the conventional lab more effective?
(d) In your opinion, what are the difficulties which face the students when they come to laboratory?

Pre-laboratory exercises

Here are the questions about the second theme 'Pre-laboratory exercises'

(a) What is your opinion about the pre-lab exercises which we had used?
(b) Do you think the pre-labs facilitate the learning in the laboratory and raise comprehension and skills or not?
(c) Does pre-lab help in understanding the nature of the experiment?
(d) Although the pre-lab was seen as a supplement to real laboratory it was also regarded as a kind of extension of the laboratory time, do you think that or not?
(e) Do you think the pre-lab provide support for those with less developed cognitive skills? Does it reduce student cognitive load?
(f) What other types of pre-lab could we use beside written material?
(g) What are the most important advantages and disadvantages in the pre-lab which we have used?
(h) If you want to talk to your colleagues at other university, what are you going to tell them about pre-lab?

Post-laboratory exercises

Here are the questions about the third theme 'Post- laboratory exercises'

(a) What are your opinions about the post-labs which we had used?
(b) What are the advantage and disadvantage of the post-labs which we had used?
(c) Do you think by post-labs we can check students understanding of the experiment?
(d) Do you use post-lab in your practical course?

H.2 Sample Interviews Notes

Introduction

Get interviewees feel more relaxed and to set them at ease:

1. Which course do you teach in this semester? ***Optics***
2. Do you prefer teaching at university or to work in other job, such as work in research centre? ***Teaching at University***.
3. In general, what are the levels of students when they come from school especially in mathematics and physics? (Or are their background in both subject is good or not?)***Some are good, but some of them are very week in their foundation in mathematics and physics***.
4. How long have you taught at the university? ***Five years***.

Laboratory Physics

Here are the answers for the questions about the first theme 'Laboratory physics'

1. In your opinions, why do you think the students are given practical physics? Or why the syllabus contains practical laboratory? ***by practical work the student confirm what they have taken in lecture, and introducing equipment***.
2. Laboratory work is regarded as an essential part in understanding physics and any science course. What skills might the laboratory work provide to students? ***increasing their ability to gather and interpret data, also, students will know more about how to use apparatuses***.
3. Do you think the laboratory as we have them now is the right way for practical work to be effective in reaching their goals? If the answer is no, how we could make the conventional lab more effective? ***No, could be by using computer simulation, your new approach also good to develop the learning in the laboratory***.
4. In your opinions, what are the difficulties which face the students when they come to laboratory? ***They have not good enough background related to theory of their experiment***.

Pre-laboratory exercises

Here are the answers for the questions about the first theme 'Pre-laboratory exercises'

1. What is your opinion about pre-lab which we had used? ***Very good***.
2. Do you think the pre-labs facilitate the learning in the laboratory and raise comprehension and skills or not? ***Yes, because it very difficult for students to know all information about an experiment in the same day he / she will undertake it.***
3. Does pre-lab help in understanding the nature of the experiment? ***Yes, because pre-lab reminds them with the theory underpinning experiment***.
4. Although the pre-lab was seen as a supplement to real laboratory it was also regarded as a kind of extension to the laboratory time, do you think that or not? ***It is not an extension to the laboratory time***.
5. Do you think the pre-lab provides support for those with less developed cognitive skills? Does it reduce student cognitive load? ***Absolutely yes,because as I told you before it very difficult for students to know all information about an experiment in the same day he / she will undertake it, especially for those with less developed cognitive skills***.
6. What other types of pre-lab could we use beside written material? ***Your new approach is good, because they can do it at home, in the time suitable for them, but also computer simulation is good***.
7. What are the most important advantages and disadvantages in the pre-lab which we have used? ***Pre-lab is simple and easy to understand***.
8. If you want to talk to your colleagues at other university, what are you going to tell them about pre-lab? ***I will advice them to use this approach***.

Post-laboratory exercises

Here are the answer for the questions about the third theme 'Post- laboratory exercise'

1. What are your opinions about the post-labs which we had used? ***Good idea***

2. What are the advantage and disadvantage of the post-labs which we had used? ***Some question relate the experiment with everyday life, by this way, the idea could remain for long time***.
3. Do you think by post-labs we can check students understanding of the experiment? ***Yes***.
4. Do you use post-lab in your practical course? ***No,because most of the time students finish their experiment in time, for that no time for such idea***.